AD701907

Technical Research Report 1160

AD

1

SUMMARY OF BESRL SURVEILLANCE RESEARCH

A. H. Birnbaum, Robert Sadacca,
R. S. Andrews, and M. A. Narva

SUPPORT SYSTEMS RESEARCH DIVISION

BESRL

U. S. Army
Behavioral Science Research Laboratory

September 1969

59

BEHAVIORAL SCIENCE RESEARCH LABORATORY

An activity of the Chief, Research and Development

J. E. UHLANER
Director

NOTICES

<u>DISTRIBUTION</u>: Primary distribution of this report has been made by BESRL. Please address correspondence concerning distribution of reports to: U. S. Army Behavioral Science Research Laboratory, Attn: CRDBSRL, Room 239, Commonwealth Building, 1320 Wilson Blvd., Arlington, Virginia 22209.

<u>FINAL DISPOSITION</u>: This report may be destroyed when it is no longer needed. Please do not return it to the U. S. Army Behavioral Science Research Laboratory.

<u>NOTE</u>: The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

Technical Research Report 1160

AD

SUMMARY OF BESRL SURVEILLANCE RESEARCH

A. H. Birnbaum, Robert Sadacca,
R. S. Andrews, and M. A. Narva

SUPPORT SYSTEMS RESEARCH DIVISION
Joseph Zeidner, Chief

U. S. ARMY BEHAVIORAL SCIENCE RESEARCH LABORATORY

Office, Chief of Research and Development
Department of the Army

Room 239, The Commonwealth Building
1320 Wilson Boulevard, Arlington, Virginia 22209

September 1969

Army Project Number
2Q662704A721
2Q662704A732

Surveillance Systems

BESRL Technical Research Reports and Technical Research Notes are intended for sponsors of R&D tasks and other research and military agencies. Any findings ready for implementation at the time of publication are presented in the latter part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

The SURVEILLANCE SYSTEMS research program of the U. S. Army Behavioral Science Research Laboratory has as its objective the production of scientific data bearing on the extraction of information from surveillance displays, and the efficient storage, retrieval, and transmission of this information within an advanced computerized image interpretation facility. Research results are used in future systems design and in the development of enhanced techniques for all phases of the interpretation process. Research is conducted under Army RDT&E Project 2Q662704A721, "Surveillance Systems," and 2Q662704A732, "Image Characteristics and Interpreter Performance," FY 1970 Work Program.

The present publication presents the major problem areas, the rationale of BESRL's approach to their solution, and the general course of research studies completed or in progress in each area of related problems. The research effort is currently organized into the following Work Units:

> The Determination of Interpreter Techniques in a Surveillance Facility--INTERPRETER TECHNIQUES
>
> Influence of Displays on Image Interpreter Performance--IMAGE INTERPRETATION DISPLAYS
>
> Intelligence Information Processing Systems--INTELLIGENCE SYSTEMS
>
> Information Processing in Advanced Image Interpretation Systems--IMAGE SYSTEMS

BESRL research in surveillance systems is conducted as an in-house effort augmented by contracts with organizations selected as having unique capabilities and facilities for research in aerial surveillance. The experimentation is in the main performed in BESRL's Information Systems Laboratory.

J. E. UHLANER, Director
U. S. Army Behavioral Science
Research Laboratory

SUMMARY OF BESRL SURVEILLANCE RESEARCH

BRIEF

Requirements:

INTERPRETER TECHNIQUES. To develop methods and procedures which maximize the accuracy, completeness, and speed with which intelligence information is derived from imagery--photographic, infrared, and radar.

IMAGE INTERPRETATION DISPLAYS. To determine how interpreter performance is affected by variations in the characteristics of the image--magnification and image quality of photos, for example, and output of infrared and radar sensors; to specify techniques for accurate and speedy reporting of information; and to select or develop efficient procedures for change detection in comparing early and late cover.

IMAGE SYSTEMS. To integrate, evaluate, and improve advanced surveillance information processing systems through laboratory simulation and to develop effective techniques for team operations, data bank utilization, and control of imagery and information flow through the system.

INTELLIGENCE SYSTEMS. To increase the speed, accuracy, and completeness of field army intelligence processing in advanced computerized systems through research on man/machine functions, procedures, and information management.

Scope of the Present Publication:

The present Technical Research Report summarizes in integrated fashion the rationale, broad objectives, and specific studies of the Surveillance Systems research programs conducted by the Support Systems Research Division of BESRL and delineates the major areas in which BESRL's manned systems experimentation has resulted in findings of interest to the Office, Chief of Research and Development, the Assistant Chief of Staff for Intelligence, the Assistant Chief of Staff for Force Development, and the U. S. Continental Army Command. Findings are applicable in optimizing performance of the human component in existing systems and in providing systems developers with information useful in design specifications for future systems.

SUMMARY OF BESRL SURVEILLANCE RESEARCH

CONTENTS

FIGURES

SUMMARY OF BESRL SURVEILLANCE RESEARCH

BACKGROUND

Military decisions require an estimate of the enemy's strength and weaknesses, his manner of deployment, and his possible courses of action. To provide the needed information, many sources of intelligence must be utilized. One major source is aerial surveillance.

A significant intermediary output of aerial surveillance systems is the imagery generated by the various sensor systems flown to cover the terrain of interest. The image interpreter is the individual who transforms the information recorded on these images into intelligence information. Not too long ago, the interpreter's problem was restricted to the interpretation of black and white photographs. Nowadays, he must also extract information from images generated by the more exotic sensors such as infrared and radar, and what is more, the information must be produced rapidly. Moreover, with the ever-increasing volume of imagery the new systems are able to generate, interpretation facilities are being inundated. Within this context, the focus is on the interpreter who must provide intelligence information meeting standards of acceptability. Based on the current state of the art, it is expected that he will remain the key information transformation agent for some time to come.

"Intelligence" is information and as such possesses characteristics of information. From the usability point of view, there are two major aspects of concern: the information content and certain information attributes. The intelligence content is important because it relates directly to the requirements imposed on the surveillance system and directly on the interpreter. The information attributes provide the means for direct empirical assessment of the information provided and thus can serve as the yardsticks for many comparisons. BESRL's manned systems research rests on the measurement of these attributes--the accuracy and completeness of information and the speed with which it is generated.

Research in the area of surveillance systems must take into account a multiplicity of variables. There are, in fact, families of variables. For example, with respect to imagery, there is concern not only with type of image--photo, infrared, and radar--but in photo imagery alone, there are vertical, oblique, and panoramic views. Photographs differ in scale and quality dimensions. They differ in content: They may depict different terrain (jungle, mountainous, swamp, desert); they may have been obtained under different weather conditions (cloud cover, snow, rain, sunny); they may show different degrees of enemy deployment in terms of target type and target numerosity. With respect to the interpreter, there are differences in ability, background, experience, and training. In requirements, there are differences as a function of echelon; for example, the commander of an army is more concerned with the global

picture than with knowing where the foxholes are. The company commander, for his part, is vitally concerned with where enemy obstacles are located. Within echelon there are different information requirements. The artillery officer is concerned with targeting information and therefore needs map coordinate data of sufficient precision that his artillery fire will include the target within the effective radius of the shell bursts. The engineering officer may wish to locate the best place to cross the river and to know the width of the river in order to plan for the requisite number of pontoons to span the river. The infantry officer whose forces are attacking may be concerned with the location of enemy ambush sites, their mine fields, etc.; in the defensive posture, he may need to know what kind of enemy forces will attack him and where they are most likely to attack. Superimposed on these requirements are the requirements that the information provided be accurate and complete and that it be provided "yesterday." There are hosts of other factors that enter into the picture, such as display, equipment, and procedures.

A surveillance system built for the Army should be able to provide for the needs of all its users. With the multiplicity of variables that must be expected to affect performance, system developers are confronted with numerous trade-off situations where decisions must be made whether to go one way or another. Data are desperately needed to assist in coming to logical conclusions.

In the area of intelligence information, BESRL research deals with at least three performance indices--accuracy, completeness, and timeliness of information. Results in terms of these indices are not always in the same direction. For example, BESRL studies indicate that, while cumulative completeness increases as a function of time, cumulative accuracy decreases. Furthermore, accuracy can be emphasized at the expense of completeness and vice versa. There are various other trade-offs involving accuracy, completeness, and time that can be made. The problem concerning the man-machine interface resides in the nature of responses interpreters can and do make when they interpret an image. The interpreter may provide a number of correct detections and identifications. However, he may also fail to detect targets actually present, he may misidentify others, and under some conditions he may report targets that are not present. In other words, the information generated by interpreters possesses an attribute of fallibility.

The research described in the present report is directed toward the improvement of information output of future surveillance, interpretation, and intelligence systems with fallout for current systems. Studies and findings are of interest to the users of these systems (interpreters, G2 and G2 Air, commanders, etc.), system designers and engineers, the Intelligence School, and the intelligence community at large.

Approach in BESRL's Surveillance Systems Research

The systems concept played a major role in the formulation of the research approach in the area of surveillance. A system can be thought of in terms of structure and function. It consists of personnel, equipment, materials, procedures, and environmental conditions. It receives input, performs operations, and provides output.

A system can also be thought of as consisting of subsystems, each with its own input, operations, and output, and each funneling its output into the larger system. System improvement can be achieved through the improvement of its subsystems and components. Assessment of subsystem effectiveness can be based on output measures of two types: 1) those based on output of the subsystems and 2) those based on total system output. The ultimate determiner of subsystem effectiveness is, of course, its contribution to the total system. However, subsystem output may be useful in itself in many studies, and at times may be the only measurable output available for assessment.

BESRL studies typically fall into two corresponding categories, those concerned with assessing subsystems or subsystem components as entities in themselves, and those concerned with the integration of subsystems or components into a larger system for total system evaluation. The approach has been to analyze current systems and conceptualizations of future systems for the purpose of study formulation and execution. For either category of study, the research is planned so as to yield empirical performance data reflective of the maximum amount of operational realism compatible with appropriate experimental control. Most studies have as a basic sequence the presentation of tactical imagery to trained Army image interpreters and the requirement that they perform their usual tasks of detection, identification, and mensuration. Their responses are then scored for accuracy (percent of responses correct), completeness (percent of targets actually present in the imagery that are reported), and speed (number of targets or reports per unit of time). The studies vary widely, depending on the number, type, and complexity of the variables being studied.

In the simplest case, little may be required beyond use of a light table and the assortment of manual aids found in the standard photo-interpreter kit--tube magnifiers, slide rule, etc. The more complex studies deal with a full scale semi-automated computerized imagery interpretation system. Interpreter, equipment, and procedures are totally interrelated. Any change in an element of such a system affects other elements in the system--not necessarily in the desired or expected direction.

BESRL's Information Systems Laboratory

To accomplish research in a timely and meaningful manner for such complex systems, which frequently are still in the conceptualization stage, an Information Systems Laboratory has been constructed within the Support Systems Research Division of BESRL. This laboratory contains light tables, full frame magnification viewers, random access slide projectors, cathode ray tubes with keyboards, pushbutton matrices, and typewriter keyboards. More important, all equipment is on-line to BESRL's CDC 3300 computer[1] which is time-shared with the normal statistical processing of research data. The time-sharing is on a priority-interrupt basis, the laboratory experimentation having priority. A detailed description of the laboratory and its operation is presented as Appendix A.

A prime virtue of the Information Systems Laboratory is its flexibility. Not only does it permit empirical simulation of computerized systems which could not otherwise be studied, but it also facilitates experimental control and data collection for studies where computerization is not requisite to the study itself. Ways in which the computer can facilitate such experiments include the following:

Computer automation provides precise control over an experiment. The experimenter may wish to present a stimulus for exactly six seconds; he may wish to present information to the subject only after certain criteria have been met; he may wish to pause when the subject has reached a certain point in the experiment. Automation guarantees that such procedures are followed exactly.

Automation provides detailed recording of events as specified by the experimenter. Every stimulus given to the subject and every response made by the subject can be recorded, including time of occurrence. The subject need not be aware that he is being timed; timing by stop watch, for example, can be a disturbing influence on the subject. The experimenter need not be physically present in cases where his presence might disturb the subject.

An automated experiment tends to be more uniform in quality. The biases that may arise when a particular person monitors the performance of a group of subjects are minimized.

Instantaneous feedback can be provided the subject. Response-dependent experiments are very difficult to perform manually if the condition for feedback depends on the responses in a complicated manner. Randomized stimuli that are not possible with manual techniques can be provided when automation is used.

---

[1] Commercial designations are given only in the interest of precise description; their mention does not constitute indorsement by BESRL or by the Army.

REVIEW OF BESRL'S SURVEILLANCE RESEARCH

The research studies completed or in progress are grouped in three categories: 1) those concerned primarily with specific tasks and functions in and of themselves without immediate regard for systems use, 2) those concerned with display requirements for accomplishing actual or conceptualized tasks, and 3) those requiring a systems context for execution because of concern with the totality of system performance as well as with the separate and interactive contributions of the various subsystems and elements.

Research to Improve Interpretation Techniques

BESRL's work in surveillance research covers imagery from exotic sensors such as infrared and radar, as well as photographic imagery. However, while there have been significant advances in the development of exotic imagery, conventional photography still constitutes an important source of military intelligence, and a substantial portion of BESRL's research is concerned with conventional photo interpretation. Many of the findings undoubtedly carry over to the interpretation of other imagery as well.

Findings from studies on interpreter techniques are intended primarily for users of the system--the interpreter, the G2 Air, the commander. These findings obviously have implications for training.

Interpretation of Photographic Imagery. A number of aspects of interpretation have been subjected to investigation, notably those concerned with trade-offs among accuracy, completeness, and time, control of imagery viewing procedures, methods for increasing the proficiency level of interpreters, and the interpretation of infrared and radar imagery.

It became apparent early in the research program that information accuracy, a measure of how much of what is reported is correct, and completeness, a measure of how much of what is actually recorded on the imagery has been correctly extracted, behave differently under many identical conditions. Figure 1 represents the relationship of accuracy and completeness to time.

While there is an increase in completeness as a function of increase in time, there is a decrease in cumulative accuracy. This drop in accuracy may be due to a propensity on the part of interpreters to respond first to the obvious, easy-to-identify objects which they can usually identify correctly. As they spend more time on the image, they exhaust the image and themselves, responding to increasingly more difficult cues, with an increasing rate of error. Every now and then, they pick up information that is correct and hence there is an increase in completeness.

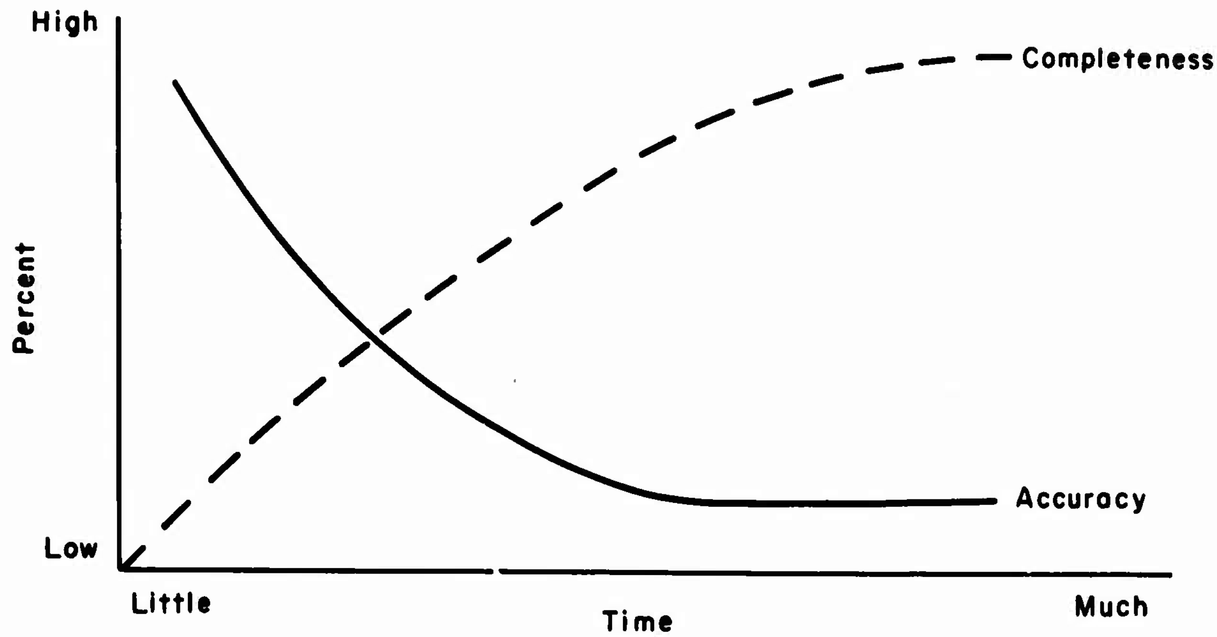


Figure 1. Accuracy and completeness in relation to time

Figure 1 represents families of curves. With changes in image quality or scale, the point at which performance levels off will change. For example, in one study (1) utilizing large-scale imagery with relatively good ground resolution, accuracy was maintained at a relatively high level for interpretation times varying from 15 seconds to three minutes per frame. This accuracy was accompanied by a continuing increase in completeness to a very acceptable level. For poorer image quality, the expectation would be that accuracy would drop more precipitously, while completeness would rise and then level off at a lower level. Although operationally obtained photo quality and scale have improved considerably in recent years, problems of image quality and scale will be present for some time to come, particularly in the case of infrared and radar imagery. There is no reason to believe that accuracy and completeness functions will behave any differently in the interpretation of infrared and radar imagery than in photo interpretation

In a study (2) concerning the performance of interpretation teams, it was also found that accuracy could be maximized at the expense of completeness and vice versa. The procedure requires that two interpreters interpret the same photo independently. A report combining the two is then generated. Accuracy can be maximized by accepting only those target identifications as correct that the two interpreters report in common. This procedure, of course, minimizes completeness, since each interpreter may have picked up correct information the other did not and this is lost in the process. On the other hand, accepting all their responses as correct minimizes accuracy but maximizes completeness. From the point of view of information use, this finding may be of great significance. Today, interpreters are not generally given instructions to

maximize accuracy at the expense of completeness or vice versa. As a consequence, the interpreters impose their own judgment, determining what the commander will finally receive. Yet there are conditions under which a commander might gladly sacrifice accuracy for completeness, or completeness for accuracy. A commander may be faced with the mission of having to eliminate a particular target under one of two sets of conditions. In the first, he may be limited in ammunition or he may be constrained from hitting non-targets. In the second, he may have an ample supply of ammunition and it may not be important whether he hits non-targets. Obviously, in the first case, emphasis is on accuracy and in the second on completeness. Yet many such decisions are made, not by the commanders who are responsible for the decisions, but by the interpreters, who are not in the best position to know which priorities govern at a given time.

Teams, of course, need not work independently. Improvement in performance can be achieved by having them operate under different procedures. For example, the size of teams can vary; members can work cooperatively. In a study of team performance, three-man teams with individuals working independently provided reports with considerably higher accuracy than did the average individual interpreter while maintaining the average interpreter's completeness (3). Fully cooperative three-man teams, on the other hand, showed gains in completeness while maintaining the accuracy rate of the individual. This latter finding reflecting gains in completeness held only for the interpretation of relatively difficult photography. To determine which aspects of team operations are important in decreasing the amount of time required for team interpretation while maintaining superiority of accuracy and/or completeness, the use of a checker who reviews the initial report provided by an interpreter was investigated (4). The findings are: When completeness and timeliness are essential, team members should check each other's work without discussion, and decisions made by the checker should constitute the final product. When a greater degree of accuracy is desired, only information agreed upon by the team members should be accepted. Maximum accuracy or completeness requires, of course, complete independence of interpretation on the part of the team members, as already discussed. Thus, depending on the particular requirements and availability of resources, various kinds of team procedures can be established to yield information content with the desired attributes.

Screening. Screening is a process of selecting, from a set of imagery, frames with high intelligence value for subsequent hot or more detailed interpretation. Frequently, the interpreter must race against time. Real-time interpretation imposes the need for rapid extraction of information for immediate use. Generally, when a roll of imagery is available, nothing is known about what is depicted in the roll. By screening, any highly significant information near the end of the roll will be reached more quickly than if interpreters were to go through normal interpretation procedures. Screening also permits the determination of the amount of information present in a roll and thus is useful in deciding whether the task of interpreting a particular roll should be assigned to a single

interpreter or to two interpreters. If the volume of information is large, the roll could be divided in half, each interpreter reporting on one half. Thus, the information contained in the roll would be available sooner.

In an early study (5) utilizing imagery at scales of approximately 1:10,000, screening performance was found to be relatively poor for times ranging from 5 seconds to 30 seconds per frame. Average accuracy was approximately 50%, increasing slightly from 5 seconds to 30 seconds per frame. In a different study (1), utilizing large scale imagery (1:2000 and 1:3000), screening performance proved considerably better. At the fastest rate of screening (15 seconds per frame), 88% of the frames were correctly classified.

Another study (6), also using relatively large-scale imagery (1:1500 to 1:3000, yielded a screening acuracy of 75% at a screening rate of approximately 10 seconds per frame. With practice, screening dropped to approximately 8 seconds per frame, some interpreters screening at rates of approximately 5 seconds per frame. This result was substantiated by a study (7) also utilizing relatively large-scale imagery (1:2000 to 1:4000). Screening accuracy improved and leveled off at 75% at a screening rate of 4 seconds per frame when rates were varied from .8 second per frame to 6 seconds per frame. Thus, it begins to appear that screening rates of 4 seconds per frame may be adequate for relatively large scale, good quality photography.

In the case of screening followed by hot reporting (8), it was found that screening adds considerably to the total processing time of the imagery but does not perceptibly affect the accuracy or completeness of the interpretation. On this basis, screening cannot be recommended as a time-saving device for hot reporting. However, this conclusion does not rule out screening as a technique for establishing interpretation priorities or procedures regarding the allocation of work to more than one interpreter.

Furthermore, interpreters looking exclusively for priority targets were more complete and less accurate than those looking for priority targets in addition to other targets on large-scale photography (1:3000 or larger) and at an average of 30 seconds per frame (9). It was also found that the interpreter who sets his own pace in interpreting the photography is more accurate than his mechanically-paced counterpart.

<u>Real-Time Interpretation</u>. Screening and hot reporting are, of course, not real-time interpretation. In real-time interpretation, the interpreter is generally confronted with a moving window display and he must report out immediately the target he detects and identifies. Reporting out implies not only naming the target but also providing map coordinates. For the interpreter to accomplish this task, the display must possess minimum characteristics in terms of scale, quality, and rate of movement. It must be linked to a quick reporting device and an automatic coordinate read-out device, both easily actuated by the interpreter. These in turn must be linked to a communication device or a

variation thereof which may involve voice communication. BESRL's real-time interpretation research is just getting under way, but results from the screening studies indicate that 4 seconds per frame are just about minimal and allow hardly sufficient time for positioning a device, providing the coordinate read-out, and communication. Applicability of the results of the screening studies rests on the assumption that the interpreters in the study either saw targets or evidence of targets (e.g., tracks) before flagging a frame for subsequent interpretation. The problem of real-time interpretation is complex and requires considerable study. Among the aspects of concern are those dealing with information loss as a function of reporting out a target. Lucrative targets may be missed because the interpreter can attend to only one target at a time.

The nature of the interpretation task is such that the information output will be affected by the way the information requirement is stated. Early, it was found that suggestibility must be considered in the instructions to the interpreter (10). When interpreters were asked to "verify the presence of tanks" in an image, they reported numerous tanks where in fact none existed. Interpreters asked merely to report out the information recorded in the image reported far fewer tanks. Extreme care is therefore indicated in specifying the task the interpreter is to perform to avoid any suggestion that may lead to error--or the verification of erroneous information.

As stated previously, trade-offs exist among the accuracy, completeness, and speed of information generated by interpreters. Interpreters working under payoff instructions emphasizing accuracy and those instructed to achieve a balance between accuracy and completeness produced significantly fewer wrong target identifications than did interpreters working under instructions emphasizing completeness (11). In the screening task, those working under instructions which emphasized accuracy produced significantly fewer wrong detections of areas of military activity. Those with instructions emphasizing completeness produced significantly more correct area detections. Another study (12) compared three methods of stating requirements:

1. A payoff method which assigns numerical weights to accuracy versus completeness.

2. A certitude method which provides a percent accuracy score which must be met for information to be reported.

3. A verbal method which states what is to be emphasized, accuracy or completeness.

Of the three methods, the verbal one appeared to be the least effective; both other methods showed promise. Thus, interpreters can vary their output as a function of the relative weight given accuracy and completeness in the instructions. However, unless the interpreters are given guidance, they will utilize their own subjective evaluations of the intelligence requirements. To obtain optimal output from the interpreter,

the requirements for the information must be stated in the appropriate manner. A standard format would be desirable. With the objective of stating information requirements in a particular military situation quantitatively, an analysis was performed to develop reliable estimates of the respective values and costs of correct and erroneous surveillance information (13). Fifty tactical situations varying considerably one from another were used. Information requirements in terms of content and cost of making errors were empirically obtained from officers in command positions. Generally, errors of omission were considered most serious and misidentifications within a category of targets least serious. False alarms and misidentifications across target categories were of intermediate cost. Errors involving certain targets, for example, tanks and missiles, were consistently judged to be more costly than errors on other targets. While the procedure was time-consuming, the feasibility of developing cost estimates of image interpretation errors was demonstrated. Such error cost data could be used to specify imagery "take" conditions more rigorously and improve the quality of the interpreter's report by making him explicitly aware of what is wanted.

Interpreter reports often are only partially accurate and seldom convey all the potential information from the imagery. The usefulness of such reports would be increased if each report carried a valid estimate of its accuracy. Normally, interpreters provide estimates of the accuracy of their reports using the terms "possible," "probable," and "positive." These are, however, subjective judgments and, although positively related to actual performance, far from perfect. Using subjective judgments and objective characteristics of performance, mathematical equations were developed to state the probability that information produced by an interpreter is correct (14). Predictions generated from the selected variables had substantial validity for accuracy of performance. Such predictions could be used in place of confidence ratings or could be used to weight the identifications made by several interpreters.

<u>Interpretation of Infrared and Radar Imagery</u>. In the area of radar (SLAR) and infrared (IR) interpretation, considerable work has been done on the interpretability of displays generated by these sensors. In the case of SLAR, research concerned the interpretability of images in two modes, the normal fixed target indication mode and the moving target indication mode. In addition, a SLAR change detection study was accomplished. In the case of infrared imagery, interpretability data were obtained for various targets as a function of varying acquisition conditions. In addition, a study was conducted concerning the effects of trading thermal sensitivity for spatial resolution or vice versa. Work is currently in progress for the development of an infrared reference key for interpretation.

Research on Displays

Research findings from studies on displays provide information on display requirements based on interpreter needs. These findings are of more immediate use to those concerned with the development of interpretation equipment and systems--system designers and engineers, in particular. The nature of the problems implies the need for discrete studies, since display requirements are of necessity tied to specific requirements imposed on interpreters.

One of the earlier studies in this area was the evaluation of stereoscopic viewing for photo interpretation (15). Stereo interpretation requires use of overlapping imagery which in turn has implications for imagery procurement and cost. Results indicate that, for general purposes, stereo viewing does not provide better performance in either accuracy or completeness than non-stereo interpretation.

Stereo imagery imposes a need for a 60% imagery overlap, with portions of the same area depicted in successive image frames. Studies were conducted to determine the effect of this overlap on performance under conditions when interpreters do not use stereo--apparently most of the time. Findings indicate that with overlapping imagery there was no increase over the no-overlap condition in accuracy of screening, negligible increases in completeness, and a substantial increase in interpretation time (6). A similar finding was obtained for the actual interpretation of overlapping imagery (8). Based on these findings, it becomes evident that the procurement and display of overlapping imagery may be detrimental under many conditions. The elimination of imagery overlap will reduce considerably the time required for the preparation of intelligence reports. In addition, the number of interpreters required to handle a given workload can be reduced; or a larger number of missions can be interpreted within a given period of time and with the same resources. The load imposed on the facility providing photo processing support will also be reduced substantially. Consequently, it would appear that imagery should generally not be procured with the overlap required for stereo viewing. If stereo is desired for purposes such as height determination, it should be requested for this purpose on an a priori basis.

Another study compared performance in the interpretation of positive and negative images (16). Concern here was with the need for presenting interpreters with positive images which require an additional processing step. Findings indicate no differences in performance in the interpretation of positive and negative transparencies. However, the subjects were experienced interpreters. Some training in the interpretation of negatives might be required to bring interpreter trainee performance up to that attained with positives. In deciding which to use, the cost of training must be balanced against the cost of providing positives.

Considering image interpretation systems for field use, many questions arise concerning alternative viewing devices. One choice to be made is between light tables and rear projection systems. Both devices

permit the display of roll film for interpretation. There are, of course, major differences. Everything else being equal, mobility requirements imposing size and weight constraints would clearly point to the light table as preferable. But everything else is not equal, and many studies need to be conducted and possible trade-offs considered in arriving at an intelligent decision. In an exploratory study, keeping levels of magnification equal for both, it was found that, in detailed interpretation and screening, there are no significant differences in performance between light table and rear projection system (17). For hot reporting, however, the light table proved superior. These findings, however, cannot be considered conclusive at this time. Moreover, in addition to the general interpreter functions--screening, hot reporting, and detailed reporting--interpreters also compare late cover with earlier cover for the purpose of change detection. Comparative cover interpretation involves the use of two sets of imagery covering the same ground area, one obtained initially and one flown later. The interpreter compares two images of the same area to determine what, if any, change has occurred in the interval between the two missions. Operationally flown comparative cover imagery is rarely congruent and there are frequently differences in orientation and scale of imagery obtained in the two missions. Departure from congruence results in degradation in both accuracy and completeness (18). A similar finding was also obtained for just locating the appropriate image on the later cover (19). This result would argue for providing the capability of rotating and variably magnifying the two images so that they can be brought into congruence. At this time, light tables do not provide such capabilities. However, rear projection systems do.

Comparative cover interpretation requires the retention of older cover for use when more recent cover is obtained, imposing a need for storage space which is at a premium in mobile Army systems. If change detection can be accomplished by means other than comparative cover interpretation, then the need for such space could be voided. With computerized interpretation facilities, it may be possible for the imagery to be interpreted as it comes in and the intelligence information stored in the computer. As new imagery for the same area is interpreted, the information can also be input. Computer matching of the two reports, by map coordinates, can be used to generate change reports. In a BESRL study of change detection methods, performance using the computer method was never exceeded by any of the comparative cover interpretation methods (20). However, prior to concluding that the computer method is an acceptable method, certain verifying experiments need to be conducted.

In addition to the presentation of imagery, projection systems can be used to display maps to obtain map coordinates. The display of map information via projection has the advantage that materials may be stored on slides or chips. Projection would also permit a more appropriate interface with a computer than is possible with hard copy material. The display of map information on a screen rather than on hard copy increases the time taken to locate an image on a map and to determine the map coordinates of an object on the map (21). The increased time to use a screen

was, however, primarily due to the fact that an imaged area frequently falls at the boundary of two map chips. Coordinate determination was not affected by the nature of the display. More definitive studies need to be conducted to determine if the time for image location on projected maps can be cut.

The Armed Forces are in process of instituting a procedure by which map coordinate location data and other such platform and sensor data are recorded in a code matrix data block, in a corner of each individual image frame. The coordinate location and other data are in binary coded form, requiring either a program to train interpreters to read the block, or a decoding device that would transform the information into alpha-numeric form. It was found that with a training program requiring little more than one hour, interpreters could be taught to read this coded information rapidly with an accuracy of 98% requiring little expenditure in time (22). It would therefore appear that alpha-numeric display of this information may not be necessary. However, in going into computerized systems where there may be a requirement to automatically read the information in the block for entry into the computer, it may be possible to provide this alpha-numeric display for relatively little added cost. Consequently, the problem whether to provide such an alpha-numeric display may be a moot question. On the other hand, the training of interpreters to read the binary-coded matrix data block would still appear to be desirable, considering the need for manual backup to the computerized systems--which do fail now and then.

The interpretability of vertical and oblique photographs was the subject of another st[illegible] (23). Objects with major dimensions in the horizontal plane were better detected and identified on vertical views; objects with major dimensions in the vertical plane were better detected and identified on the oblique views. It was also found that objects in the foreground of oblique views were generally better detected than those in the foreground on the vertical views. The reverse was found for objects in the background on the oblique view. Considering that for forward oblique imagery what is background on a given frame may be foreground on subsequent frames, it may be desirable for some purposes to acquire oblique imagery. For mensuration purposes, however, the oblique view is inferior to the vertical view. Also to be considered is that these findings come from a study where the average scale on the oblique view was essentially that of the vertical view.

Recent review and study of the Army's photo interpretation kit, which includes the most common tools of the interpretation trade such as magnifiers, stereo viewers, and measuring scales, led to the conclusion that all the items in the PI kit may be used at one time or another. Not all the tools needed for a complete capability are included in the kits (24). With emphasis on the need for additional aids for mensuration and plotting, it was further concluded that an abbreviated kit should be made available for personal use for activities performed away from an interpretation facility. The remainder of the items should be issued from the facility's supplies for use by interpreters within the facility.

As part of this effort, a new design for tube magnifier reticles was conceptualized, as were also plotting templates for panoramic imagery--currently not available. Steps should be taken to provide interpreters with these modified magnifiers and plotting templates.

Interpretation Keys and References. Image interpreters often make use of interpretation keys or references. These keys depict objects and can thus be used as comparators in making a particular interpretation. For example, if an interpreter suspects that a particular object in an image is a specific kind of tank, he can go to the key and compare the imaged object with a picture of the tank. Keys can take different forms; for example, the key just described is a "rights" key depicting objects as they appear. Another type of key is an "error" key, a reference that alerts interpreters to errors commonly made in interpretation. Error keys proved superior to rights keys in affecting performance (25). Essentially, the error keys improved accuracy without adversely affecting completeness.

As part of BESRL's effort, a number of experimental keys have been developed including a mini-key for U. S. equipment which can be used as a handy condensed reference (in place of the large and bulky keys currently available) and a Vietnam error key which considerably improves interpreter performance. In addition to, or instead of, photographic keys, schematic presentations can be used. Different views of an object can be presented and at different photo scales. It appears (26) that schematic presentations are as good as photographic presentations. So far, BESRL's work on keys has concerned itself primarily with photographic imagery. More recently, work has been initiated to determine what types of key are best for use with infrared imagery.

Research on Image Quality. The quality of the image is of major concern to image interpretation. From a general point of view, there is a direct relationship between image quality and the interpretability of an image. An understanding of the relationship between performance and image quality would permit determination of the points of diminishing returns for image quality. Moreover, estimates of the quality of imagery obtained in the field could be very useful for determining the interpretability of the imagery for particular purposes and could be used to reduce the amount of imagery to be interpreted. Furthermore, measurement of image quality in the field can be an aid in determining the probability of the accuracy of a particular interpretation.

However, image quality is not a unitary dimension. Factors such as granularity, acutance, contrast, resolution, and scale are all components of image quality. Definitive studies relating these dimensions to performance would be of very large magnitude. Experimentation focusing on factors that may have an effect on image quality and that can be controlled--or compensated for--was considered more feasible. Research was therefore conducted on factors of image motion, atmospheric haze, and scale as they affect image degradation (27). Results indicate that these factors can be accounted for by a single factor, the ground resolvable distance.

Since measurement of image quality could be exceedingly useful in the field, a study of the effects of quality judgments by interpreters regarding the interpretability of images was undertaken (28). The average judgments by a number of interpreters proved very reliable and possessed a fair amount of validity. An image quality catalog was developed for use by interpreters. This catalog presents images in terms of three dimensions: scene complexity, photo scale and image sharpness. Data on the interpretability of the images were obtained and the feasibility of using these images to obtain measurements of image quality was demonstrated (29). The catalog measures were found to be considerably more valid than average quality judgments made by interpreters. The interpreter using this catalog compares the images he is interpreting with the images in the catalog and selects the image in the catalog that most closely resembles in quality the image he is interpreting. This preliminary study merely established the feasibility of the approach. The generalizability of the catalog requires further experimentation.

In recent years, the transmission of imagery from aircraft to ground has come to be of major concern. Real-time or near real-time interpretation is becoming increasingly more important and hence the time saved by not having to wait for the return of the aircraft becomes significant. Further, with real-time transmission, the receipt of the imagery may make a mission at least partly successful even if the aircraft does not return. Unfortunately, the higher the image resolution desired, the more bandwidth is required for transmission, and large amounts of imagery to be transmitted at high resolution could preempt the bandwidth required for other messages. Although transmission time can be traded for bandwidth to achieve a higher level of resolution, this step does not solve the problem, because of the ever-increasing time delay from transmission to receipt of the imagery.

From the point of view of the utility of the imagery received on the ground, the problem reduces to determining the image scale-quality required for the interpreter to be able to interpret the imagery, or at least to determine which portion of the imagery should be retransmitted with more resolution. The latter problem concerning screening was investigated in an exploratory study (7). The interpreter's ability to correctly classify 70mm photo frames at a scale varying from 1:2000 to 1:4000 and at screening rates varying from .8 second per frame to 6 seconds per frame declines as scale, image quality, and time allotted for the task decreases. Maximizing any of these three dimensions results in improved performance. Thus, poorer quality imagery can be adequately screened by allowing more time for screening. More definitive studies are planned to home in on the resolution, scale, and screening rate requirements for adequate screening of transmitted imagery.

SYSTEMS STUDIES

BESRL's systems studies are concerned with a number of different facets relating to system development and system use. They serve the purposes of integrating findings from many relevant efforts, of conceptualizing and evaluating system alternatives, and of conceptualizing and testing various aspects of system and computer use to maximize the capability of the system. The expectation underlying much of this effort is that future interpretation facilities will have computers, and that these computers can serve for many more purposes than the mere storage and retrieval of data and the computation required for obtaining map coordinates. Within this area, BESRL is conducting research to develop and use a systems measurement methodology, developing procedures by means of which the computer can assist man in the decision process, and determining how best to use computerized interpretation facilities for the maintenance or improvement of interpreter proficiency.

Systems Measurement Methodology

The Information Systems Laboratory provides the physical facility necessary for total system research in the area of image interpretation. Within this laboratory, a wide variety of image interpretation systems can be configured for simulation purposes even though the system to be simulated is only in the conceptualization (pre-QMR) stage. However, meaningful systems research in terms of performance evaluation requires a vehicle or methodology for exercising the simulation. Such a methodology should permit realistic simulation of image interpreter facility operations in a tactical situation with sufficient laboratory control for derivation of pertinent quantitative performance measures. To that end, a Standard Systems Measurement Bed (SSMB) was developed, and a semi-automated Tactical Image Interpretation Facility (TIIF) was conceptualized and simulated as a means of evaluating the utility of the SSMB in comparing image interpretation systems at the system, subsystem, function, and subfunction levels (30). Constructing the SSMB involved three main tasks: 1) identifying typical image interpretation processes to be represented, 2) review of available materials and selection of those providing suitable problems and exercises in the context of a reasonable scenario, and 3) determination of appropriate measures and data collection techniques to insure adequacy and interpretability of results. The ramifications of these steps are described in Appendix B.

Corps level was selected as the echelon of operation to be simulated because it has organically assigned aircraft and would have the diversity of activities and requirements to impose a taxing workload on a TIIF. Guided by Army doctrine for corps level operations, the desired test characteristics were specified for the major test components: inputs, requirements, and outputs as shown in Table B-2. On the above basis, imagery was selected, SOP's and reporting requirements were established, and supporting documentation (as detailed in Appendix B) was prepared. A coherent scenario was written to effectively bond together all the SSMB elements. Concurrently, data collection and processing plans were formulated.

Several trial runs with subsequent modification and refinement resulted in a package of selected and scheduled input materials, uniform and realistic processing requirements, and systematic data collection and scoring techniques imbedded in a reasonable 5-day scenario. The package consists of 56 rolls of imagery, including infrared, side-looking-radar, and a variety of day and night photography representing the quantities and types that might be acquired during an actual military operation. The SSMB is sufficiently open-ended that new types of imagery or terrain and cover can easily be added if circumstances warrant. All materials and procedures for administration, as well as instructional materials for the image interpreter subjects, are documented. Figure 2 shows how the SSMB would be implemented.

The final evaluation of the SSMB involved full-scale application in the BESRL Information Systems Laboratory. This application was a five-step process: 1) conceptualization of a representative or model system to be evaluated, 2) building a simulation of the system in the laboratory, 3) exercising the simulation using the SSMB, 4) collection and analysis of performance data during the exercise, and 5) evaluating the performance of the simulated system as a means of assessing the SSMB.

The experimental model concept was based primarily on analysis of Army requirements for a TIIF in the current time frame. These requirements were used to define the basic functions and tasks needed for a fieldable semiautomated TIIF. Steps involved in the model development are described in Appendix B. The model TIIF specifies six image interpretation stations which can accommodate up to eight interpreters. The floor plan of the model is shown in Figure 3. Guidelines were established for construction of the simulation in the laboratory with a goal of duplicating the model in all functional aspects and closely approximating it in terms of physical dimensions and configuration of equipment. The floor plan (Figure 4) illustrates how closely the laboratory simulation resembles the conceptualized model.

A series of full-scale tests of the SSMB was conducted, starting with a portion of the system and gradually involving more and more of the system until the total system was included. Trained image interpreters manned the system for the five days of each test. Data were collected during the tests. At the end, the experimenter and observers collaborated to reconstruct all test events and to score, reduce, and analyze the data. Normally, evaluation involves assessing total system performance in terms of established criteria and ascertaining the relative contribution of the various subsystems, functions, and subfunctions. Various man-procedure-equipment factors are carefully examined to find ways in which the configuration might be changed to provide improved performance on subsequent iterations. In the present instance, the purpose was to evaluate the SSMB as a vehicle for obtaining the required data, and the analyses focused on the pertinence and interpretability of the data.

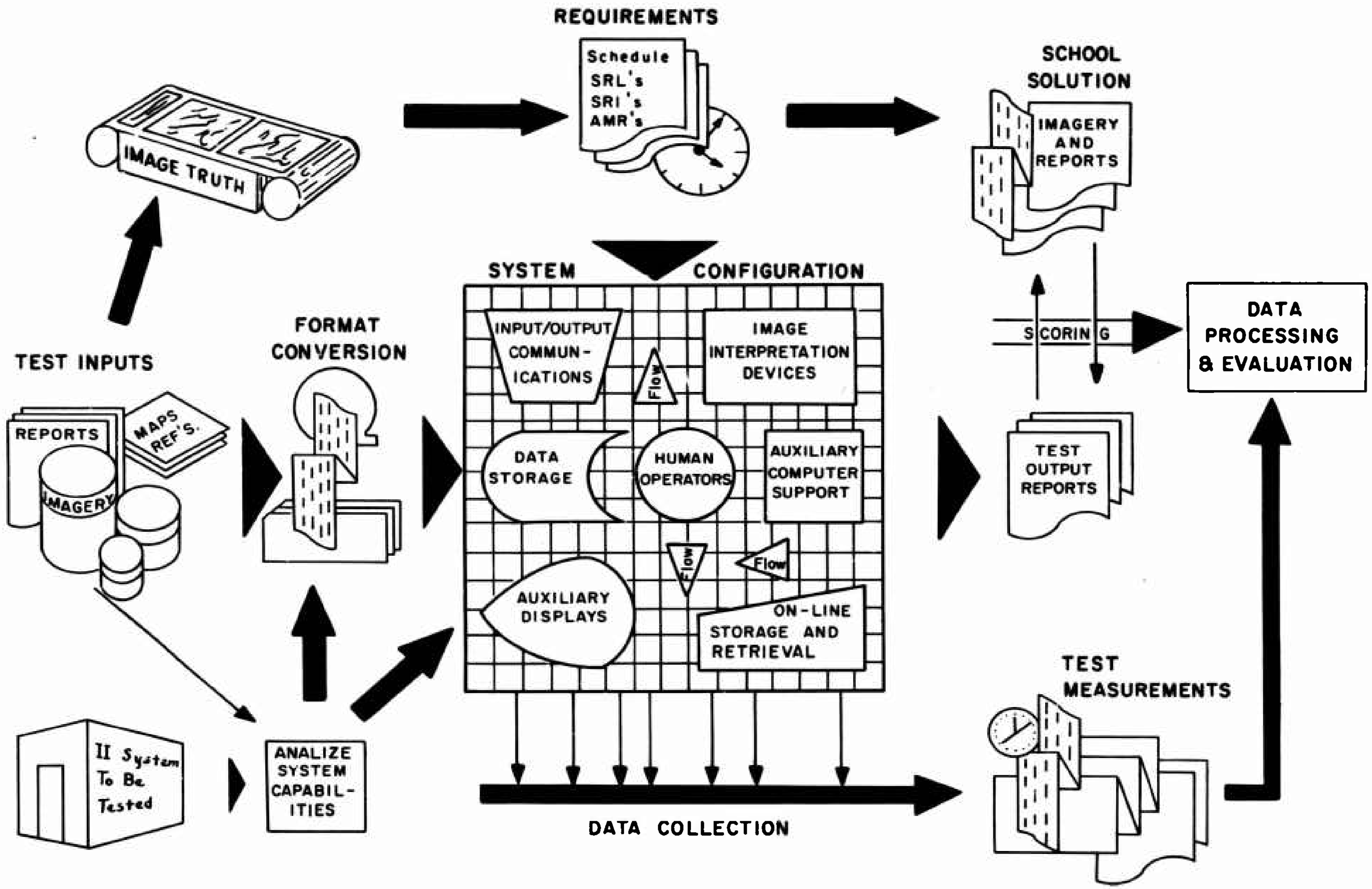
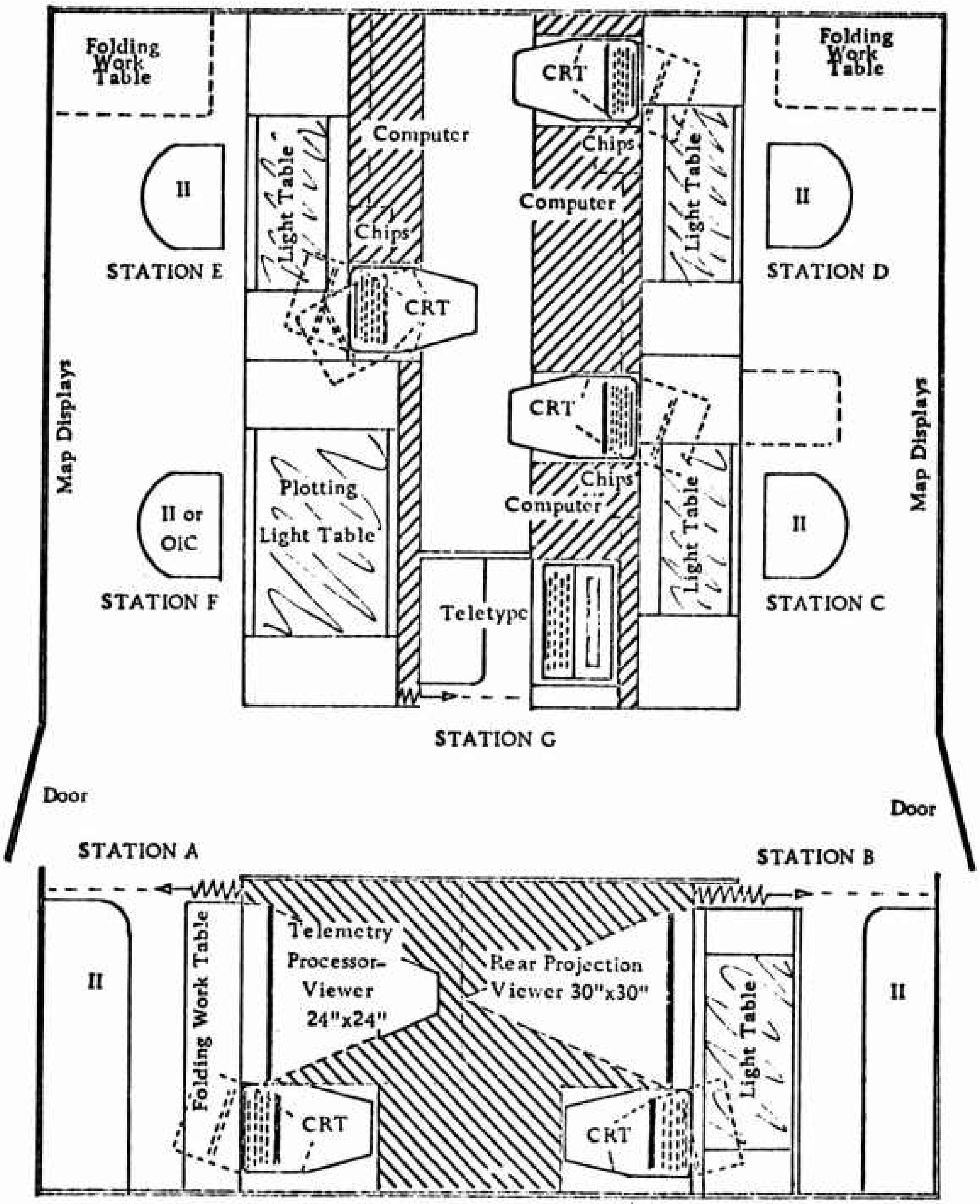


Figure 2. Implementation of the SSMB in the BESRL Information Systems Laboratory



*Stations A through E have access to the computer. Scale 1" = 3 feet

Figure 3. Tactical Image Interpretation Facility model concept

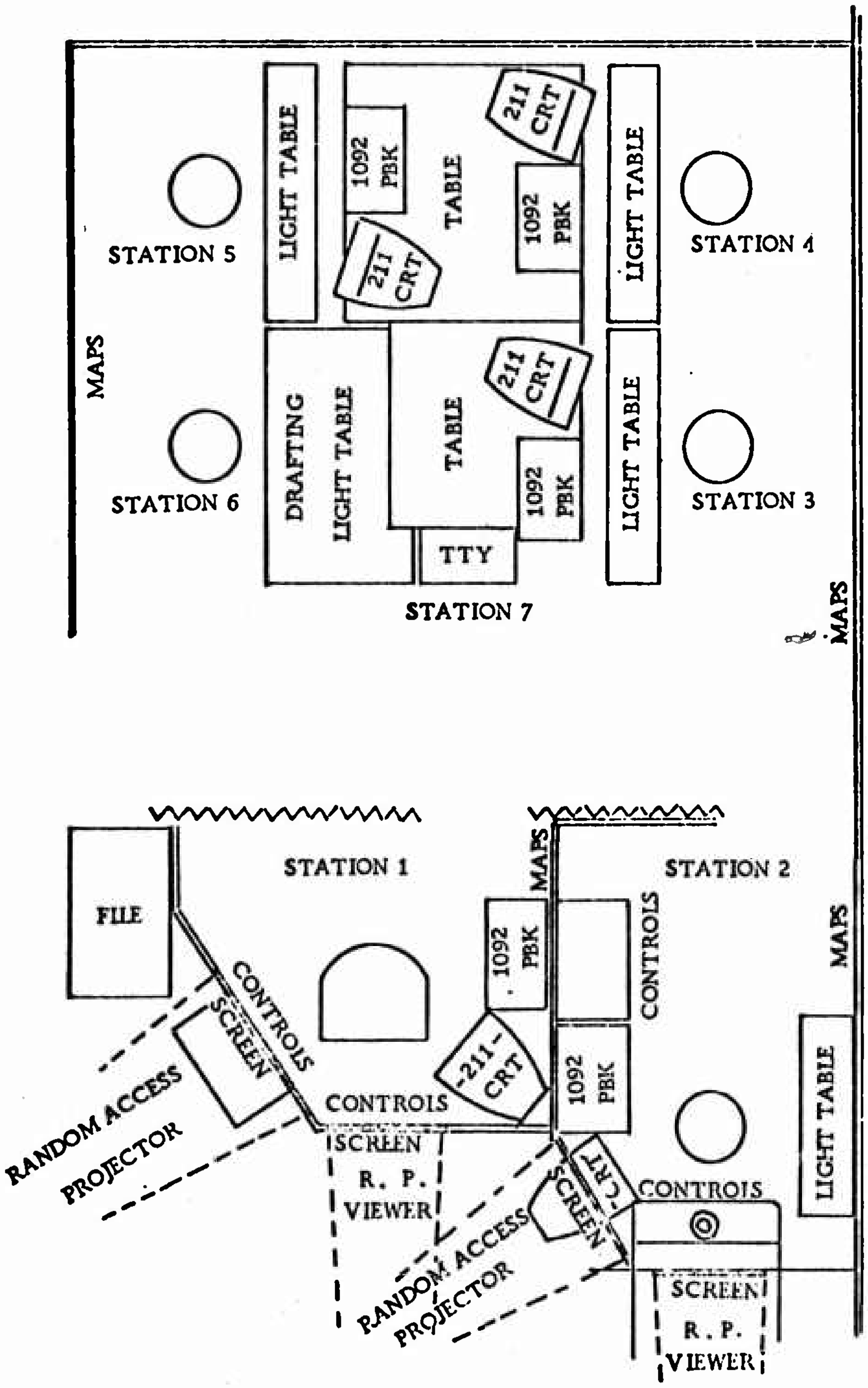


Figure 4. Floor plan for the laboratory simulation

While not yet completed, the analyses to date clearly indicate the feasibility of the SSMB for its stated purpose. Twelve different timeliness measures, 13 accuracy measures, and 12 completeness measures were obtained. Additional scores could be derived by combining and or weighting the basic measures in a variety of ways to reflect the relative importance the intelligence staff assigns to accuracy, completeness, and timeliness, as well as to type and content of the image interpreter reports. Diagnostic measures were also obtained on the performance of each man-station combination, the relative amount of time spent in each of the various functions and subfunctions, and the various verbal, transfer, and movement links of man and station.

The SSMB has been demonstrated to be a valuable tool for assessing alternative image interpretation systems and system configurations while the systems are still in the conceptualization (pre-QMR) stage or early development (before prototype) stage. It permits evaluation of total system effectiveness and of the contribution of the various system elements to that effectiveness. It enables dissection of man-procedure-equipment interactions, providing clear indications of how such relationships can be optimized for improved efficiency and effectiveness. The SSMB, together with the Information Systems Laboratory, provides a unique capability for realizing appreciable savings in time, effort, and funds through empirical determination of system design and operating characteristics early in the research and development cycle rather than through the more customary start-stop-redesign or retrofit route.

Man/Computer Decision Processes

In a systems context, image interpreters and the system computer can be viewed as components whose task is to perform their functions so as to contribute maximally to the system output. The system output is intended to satisfy levied mission requirements. The study of man/computer decision processes is an attempt to increase the meaningfulness and utility of the interpretation system output by tailoring, with the aid of a computer, the quality and quantity of interpreter reports to the needs of the military situation.

A series of research studies is being conducted to determine whether a general decision model involving the evaluation of action alternatives through the use of pay-off matrices and probability estimates can be used to help control interpreter output. The pay-off matrix states the relative value of each action alternative (in this case, making various alternative interpretation reports), given each possible true state or condition (in this case, the actual targets in the area covered by the photographs). The model is probabilistic in the sense that it admits that the true state or condition confronting the decision maker is seldom positively known, and it is necessary to hypothesize a set of mutually exclusive and exhaustive true states and to estimate their relative probability (in this case, the probability that the object being interpreted is each of the targets for which the interpreter is searching).

In the general model, when the values in the pay-off matrix are weighted or multiplied by the probabilities of the true states, the product is the expected value of each of the decision alternatives. In the application to image interpretation, a simplification can be effected through considering only the costs of making erroneous interpretation reports. Under the assumption that a correct interpretation has no cost, zeros can be inserted in the pay-off matrix for every report alternative corresponding exactly with a true state. This procedure makes the task of obtaining values to place in the matrix considerably easier, as only costs need be considered rather than both costs and gains. The cost matrix, when multiplied by the target probability vector, yields the expected cost of each reporting alternative; the decision rule is to choose the alternative with the minimum expected cost.

To apply the expected cost approach to an image interpretation system, two types of data are needed. The interpreter would provide the information on which the target probability vector would be generated. The cost data would have to be supplied by the commander or his staff in terms of some arbitrary unit denoting the relative seriousness or cost to current mission of each of the possible image interpreter errors. Table 1 contains an abbreviated sample matrix with a set of hypothetical costs.

Table 1

ABBREVIATED SAMPLE MATRIX SHOWING HYPOTHETICAL DATA FOR EXPECTED COSTS IN PHOTOINTERPRETATION SYSTEMS

	TRUTH					
Identification	Tank	Truck	Missile	Nothing	Probability Vector	Expected Cost
Tank	0	2	5	4	.40	2.3
Truck	3	0	6	2	.20	3.2
Missile	2	2	0	5	.30	1.7
Nothing	8	4	14	0	.10	8.2
Vehicle	3	1	6	2		3.4
Weapon	3	2	4	2		3.0

The highest cost in the matrix is the error of omitting a missile--reporting nothing when in fact a missile is there. The lowest cost is the imprecision error of calling a truck simply a vehicle--some small cost is associated with insufficient specificity. Misidentification errors (identifying a tank as a truck) and inventive errors (identifying a non-target image as a target) are usually intermediate in cost. Note that perfect information has no cost. In the example the image interpreter has identified a given object on the imagery as most probably a

tank. However, there is only a 40% probability that the given object is a tank, 20% that it is a truck, 30% that it is a missile, and 10% that it is really not a military object at all. When the cost matrix is multiplied by the associated probabilities, the expected costs of the reporting alternatives are produced as shown in the last column. In this instance, the lowest expected cost is for the response "Missile." Therefore, the object in question would be reported as a "Missile" even though it is more probably a tank.

One way such information can be used is to control the quantity and quality of information output by the system as shown in Figure 5. The intelligence officer (G2) to whom the image interpretation facility's report is being sent can set a quality standard for acceptance of the information. This standard is a single number representing the maximum acceptable expected cost. Suppose, in the example, the G2 has set this maximum cost at 2.0. Only responses with an expected cost at or below this maximum cost would be reported. The missile response would qualify even though the probability that the target is truly a missile is only 30%. If the G2 had set a more stringent cost, the system would be forced to improve the probability of the identification through using other interpreters or seeking corroborative information or better photographic coverage. Setting a generous standard allows the system to produce a large amount of information, but the average accuracy of the information may be low.

On a conceptual level, the expected cost approach seems to have merit. Yet the implementation of such a procedure is dependent not only on having a computer in the system, but also on obtaining reliable probability estimates from the interpreters and valid costs from the commander or his staff. A final consideration is that obtaining these data not impose unreasonable time demands on the personnel involved. BESRL has undertaken research to develop the appropriate methodology for making practicable both the estimation of probabilities and the construction of error cost matrices. Some of these studies are described below.

One study in the probability area (14) investigated the feasibility of devising a more systematic method of predicting the accuracy of reports made by photo interpreters. Using simple and easily obtainable subjective judgments and objective characteristics of an interpreter's performance, mathematical equations were developed to estimate the probability that information produced by an interpreter is in fact correct. These equations have substantial validity in predicting the accuracy of interpreter performance. However, procedures for obtaining the equations are somewhat cumbersome and the approach is not a very efficient way to generate a probability vector in comparison with the single probability prediction. Should changes affecting the variables occur over time, the requirement to update and modify the equation imposes considerable burden on the system. Consequently, it was decided to investigate intensively the confidence judgment variable, which in essence is a direct probability estimate made by the interpreter, since it was one of the strongest predictors in the above study and would seem to lend itself readily to the generation of an entire probability vector.

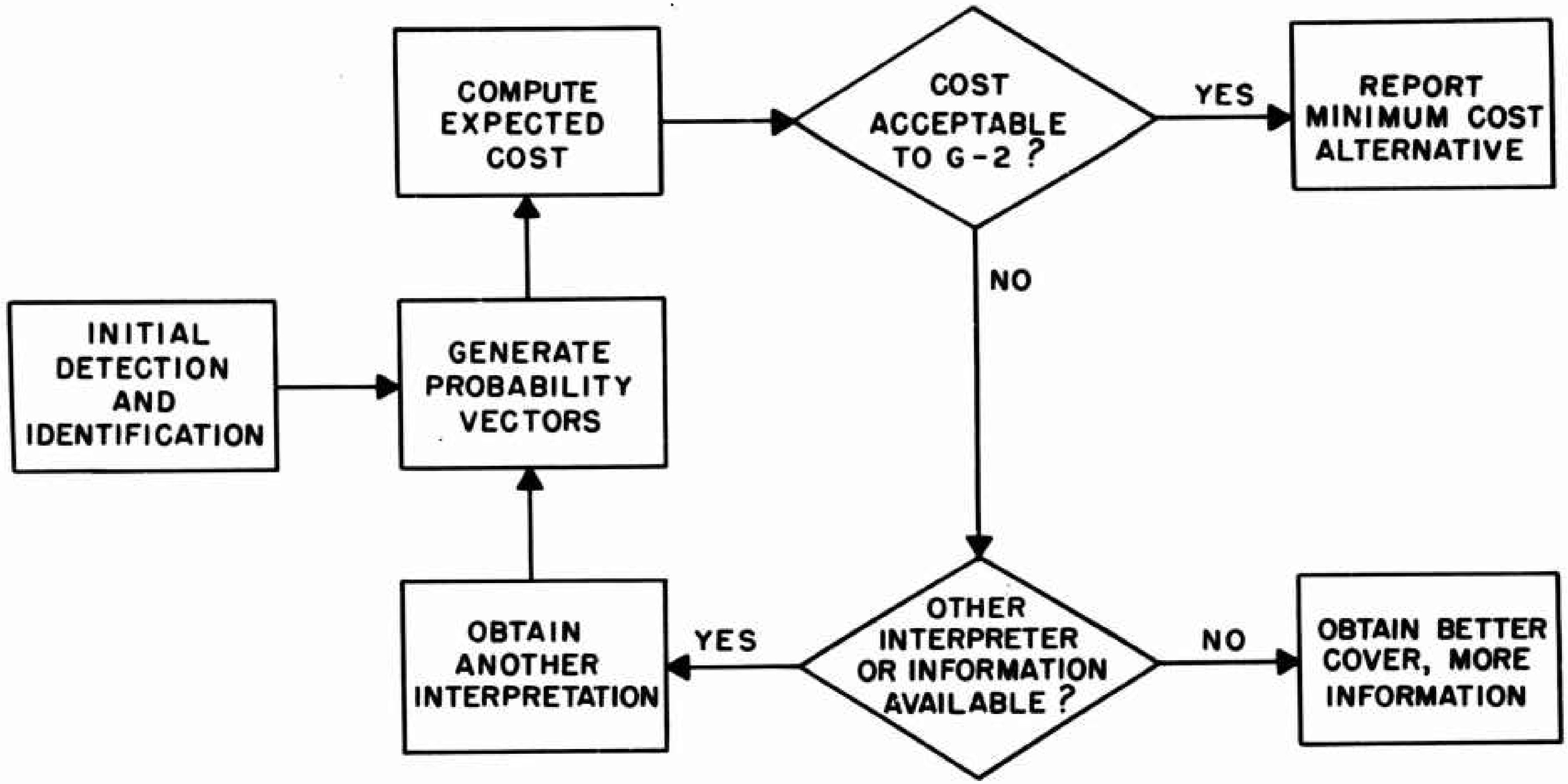


Figure 5. Computerized control and evaluation of system output for an image interpretation facility

The study compared three techniques for obtaining estimates of probable accuracy: the Direct Name Vector (DNV), the Derived Name Vector-Experimental (DNVE), and the Derived Name Vector-Control (DNVC). The DNV technique imposes the task of directly judging the total target probability and the probabilities of selected specific target names. The DNVE technique requires direct estimation of the probability that the object belongs in a general target category, as well as the probability that it belongs at three specific levels of target description, including the most likely specific target name. The DNVC technique imposes the task of directly judging the total target probability and the probability of the most likely specific target name. Each of the three judgment techniques proved superior to multiple regression techniques for adjusting the interpreter's probability estimates. A simple linear adjustment of the interpreter's original estimates was more effective than the complex multiple regression technique. Of the three techniques investigated, the DNV technique appeared to maximize the amount of information which could be obtained from the interpreters. Performance in estimating probable accuracy deteriorated for all groups when transferred to the free-search task, implying that training should probably use free-search rather than annotated imagery. Studies to further enhance the interpreter's ability to estimate probabilities accurately utilizing the DNV are in progress.

The other basic input data for the expected cost approach are the values in the error cost matrix. The first study conducted explored the basic feasibility of generating matrices containing indexes of the relative costs of errors of different kinds (13). The following objectives were pursued in the context of a surveillance information processing system:

1. Explore the problems in constructing cost matrices, in particular problems of specifying target categories for column and row headings and assigning values to individual cells.

2. Study the impact of different military situations on the cost matrices, in particular the effect of differences in the military situation on intelligence information requirements as reflected in the target categories and the cost of various types of error (omission, inventive, misidentification).

3. Devise procedures whereby error cost matrices could be readily generated in the field.

Analysis of the data revealed that judged cost of errors varied considerably with type of error involved. Errors of omission were considered most serious, misidentifications within a category of targets least serious. Inventive errors and misidentifications across target categories were of intermediate cost. Average costs assigned in one situation were not substantially different from those assigned in other situations. However, some situational effects were noted; for example, the cost of errors in identifying mine fields was greater in attack than in defense

situations. Errors involving certain targets were consistently judged more costly than errors on other targets. Errors in identifying tanks and missiles were considered the most serious and identification of supply facilities the least serious, regardless of situation.

The procedure used to obtain the error cost estimates was operationally difficult and time-consuming, and the quantitative estimates obtained were of low inter-judge reliability. On the other hand, when the officers were asked to rank targets subjectively according to the positive value or importance of information about them, the task was performed adequately and well, and inter-judge reliability of the values was high. Thus, though the feasibility of obtaining cost estimates of interpretation errors was demonstrated, the close relationship between target importance rankings and the more elaborate cost estimates, plus the greater inter-judge reliability of the rankings, suggested a short-cut method based on a ranking procedure which could be used in the field to generate cost matrices.

A second study was conducted to capitalize on the above findings and develop a practical field methodology for obtaining error cost estimates of improved reliability and validity (31). Practical considerations imposed several important requirements: 1) The method sought must be capable of providing valid costs on an interval scale; 2) it must require no more than four hours of a decision maker's time to establish all costs; and 3) it must require neither special equipment nor lengthy training of the decision maker for data collection. Direct judgments of cost for a selected set of different possible errors and direct judgments of value for correct reports of every type of target were obtained. These costs and values were then employed as variables in a multiple regression equation for the prediction of unjudged error costs.

The short-cut method for quantifying the subjective costs of large numbers of image classification errors via direct magnitude estimation of a sample of errors and the subsequent prediction of all remaining errors was sufficiently promising to warrant further research efforts aimed at refining the method and evaluating its effectiveness in an operational field type setting for use in conjunction with probability vector estimates provided by interpreters. The large number of errors which must be judged or predicted and the generation of appropriate weights for the multiple regression prediction equation preclude this approach where computer assistance is unavailable. However, with computers comparable to those in existing or planned image interpretation facilities, the task is easily manageable.

Computer Techniques for Training Image Interpreters

Sensor systems and aerial platforms are being continually improved by the military services to obtain better surveillance cover. With each advance in sensor/platform capability, the need for a continuous training program designed to maintain and enhance the proficiency of interpreters becomes more imperative. The Information Systems Laboratory

provides an excellent vehicle for conducting research to evaluate new techniques for on-job training of image interpreters. The advanced image interpretation facilities being developed by the Services contain, like the Laboratory, various viewing and input/output devices and one or more computers with associated data bases. Such facilities can be used as automated teaching machines to implement programs for the maintenance and improvement of the proficiency of personnel assigned to the facilities. A summary of completed and on-going research on a number of promising training techniques is presented below.

One study is concerned with comparing branching and linear instructional programs for training in target identification (32). A branching program permits the presentation of instructional material to vary depending on the progress of the student through the course. A linear program presents the instructional material in a fixed order regardless of demonstrated mastery. Response-sensitive and response-insensitive feedback were also compared. Response-sensitive feedback provides the student with information appropriate to the specific answer he has given. If he gives a wrong answer, the feedback explains why his answer is wrong. Response-insensitive feedback provides only the correct answer. Both these comparisons have implications for the computer capacity and software complexity necessary for computer-aided instruction (CAI) systems, the branching and response-sensitive methods requiring more support than the linear and response-insensitive methods. Considerable learning was accomplished through the medium of computer-assisted instruction. The findings also indicated that the instructional approaches requiring greater computer capacity--response-sensitive feedback and branching programs--may yield more efficient learning. The possible use of the computer within an advanced tactical image interpretation facility for maintaining and enhancing personnel proficiency should be kept in mind in the selection and employment of computer and associated input/output equipment.

In a rapidly changing environment, CAI, as usually applied, has the disadvantage of requiring considerable time for course preparation. Material to be learned must be carefully formatted and programmed for presentation in discrete knowledge bits. Try-outs of the instructional units are necessary to insure effective learning. Another approach to CAI, applicable where a large data bank is associated with a computer, is to allow the student to interact directly with the computer without the mediation of a course author. Material to be learned is presumed to be present in the system data bank and is accessed through use of the data bank index. An advantage over conventional CAI is that, as soon as information becomes part of the data bank, it can become incorporated into a programmed learning routine. Two on-going studies are exploring how this modified approach to CAI may be accomplished in an advanced image interpretation facility.

In the first study, an open-ended general purpose image interpreter Computer Aided Instruction (CAI) program will be designed in which target types will not be broken down into component features but the interpreter

will be allowed to make his discriminations based on whatever cues he can discover in the material presented. It will be assumed that the image interpretation system data bank contains examples of the targets to be learned. The general purpose program uses the data bank index to find target examples, assigns numbers to each target example, controls the presentation of the examples, monitors students' answers, and supplies appropriate feedback. The principle guiding the presentation of target examples is to present to the student at any given time a target example selected randomly from those targets and examples that the student is equally likely not to be able to correctly identify. When the student has demonstrated that he can correctly identify each target a predetermined number of times, the course is over. A generalized flow diagram of this instructional strategy is presented in Figure 6. In the experimental evaluation, this approach will be contrasted with the more conventional CAI programs developed in the previously described study.

In the second study, a more conventional structured course on the interpretation of infrared (IR) imagery will be contrasted with an approach which can perhaps best be described as "browsing." In browsing, the student searches out through the data bank index and studies material concerning sensor/target characteristics. The value of introducing practical exercises into the learning process will also be explored. The amount of computer software and CAI authorship involved in implementing the browsing approach is minimal. Whether it is an effective training technique will be determined empirically.

The CAI methods described above are directed primarily toward enhancing image interpreters' identification accuracy and completeness. Another experiment was designed to assess techniques for increasing image interpreters' detection speed while maintaining initial accuracy and completeness levels (33). Two search strategies devised to reduce inefficient search behavior while increasing the completeness with which images are searched were coupled with a "speed-reading" technique for reducing visual fixation times and expanding the effective size of interpreters' perceptual field. One search strategy employed a systematic geometrical scan pattern in which the subjects searched across the image very much as they would a page in English--from top to bottom, scanning from left to right. The other search strategy was tactically oriented. The students were taught to allow their search to be guided by the significant tactical features and lines of communication present in the image--ridges, valleys, roads, rivers, trails, for example. These two search strategies were compared with each other and with a free-search strategy in which the students were not trained to search the imagery in any particular fashion. They were not given special visual fixation/field expansion training, but were given special practice and feedback designed to increase search speed. Results indicate that interpreters can be trained to increase their speed considerably with little loss in accuracy and completeness. This desirable result was achieved simply by forcing interpreters to gradually decrease their search time per image. Further, completeness rates can be maintained while increasing speed through training subjects to scan images systematically. If the concomitant

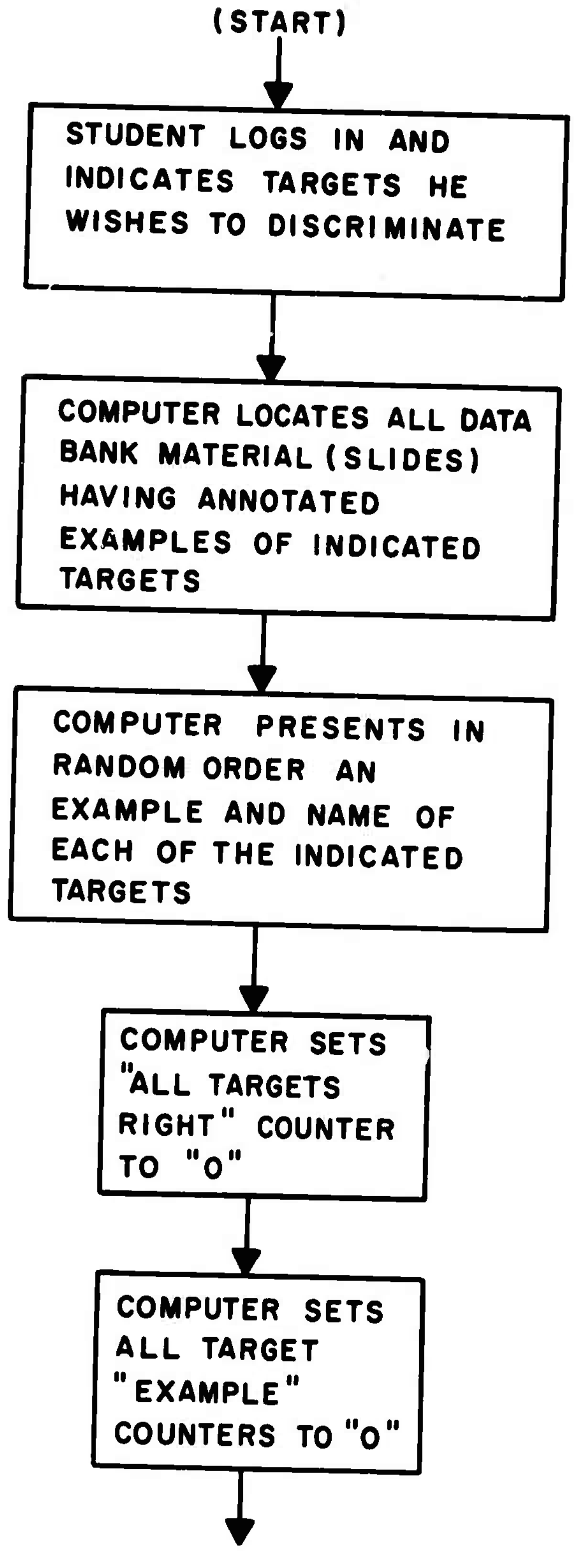


Figure 6. Generalized flow diagram for data bank utilization in open-ended Computer-Aided Instruction (CAI)

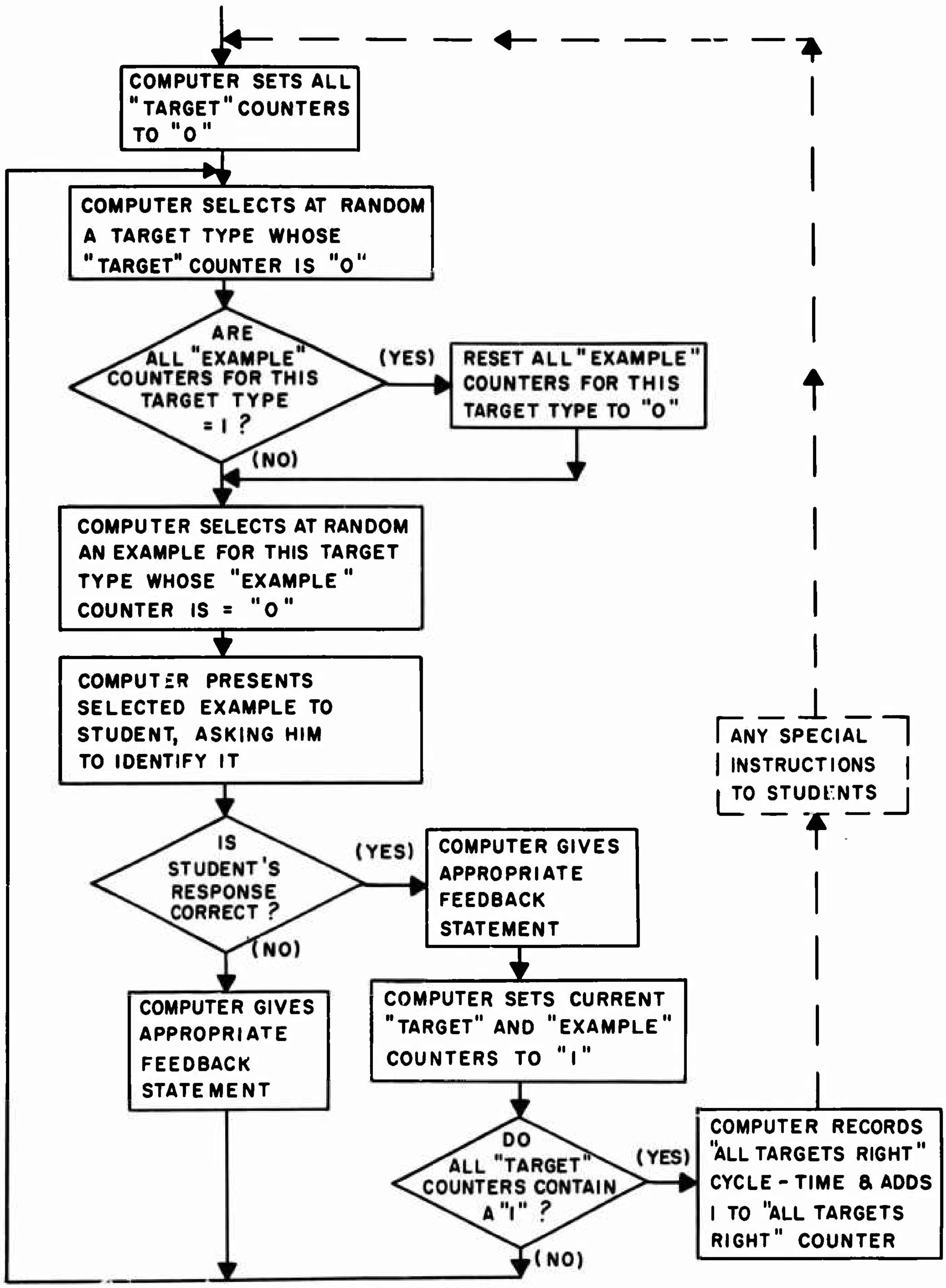


Figure 6. Continued

tendency to make more inventive errors can be eliminated, training in the use of a geometric search pattern may prove an effective procedure also. In fact, reducing the number of inventive error responses would raise detection accuracy and most probably increase speed for all methods. Follow-up research applying the geometric and speed techniques to searching real-time or moving imagery is currently under way.

Another study concerned error avoidance training. Interpreters can make the error of reporting targets where none really exist. The frequency of these inventive errors depends on a number of factors--the scale, quality, and complexity of the imagery, the number of natural and man-made objects in the imagery that can be confused with military targets, and the experience and training of the interpreters. The instructional unit developed is based on the rationale that through studying the kinds of error made by interpreters who have previously examined similar imagery, interpreters can learn to avoid making the same errors (33). Error avoidance training proved to be an effective technique for reducing the number of inventive errors made by interpreters. An advantage of the technique is that it can be applied in the classroom as well as in the field, using examples specific to particular unit operations.

A final study concerns team consensus feedback (34). Results from a number of studies conducted at BESRL have indicated that image interpreters working in teams can produce more complete and accurate information than interpreters working alone. The consensual judgment of team members has been found to be especially effective in reducing the number of identification errors made by single interpreters. These results led to the development of experimental training methods based on teams' providing feedback to the individual members comprising the teams. The identifications agreed upon by team members, being on the whole more accurate and complete than those of the average individual team member, can provide feedback to the individual team member as to the adequacy of his own identifications. An advantage of this approach is that no special instructional materials or preparation are required. Teams can be formed in the field on an ad hoc basis during operational lulls. Any previously interpreted imagery that happens to be available can be used.

A series of four experiments was conducted to evaluate the effectiveness of training methods based on team consensus feedback. In the last experiment, the two most promising techniques identified in earlier research, the <u>serial consensus</u> and <u>immediate consensus</u> methods, were compared with each other and with a control procedure (individuals practicing alone). In the serial consensus method each man performs initial interpretation on a different stereo pair. The men then move to their teammates' positions, check identifications already made, and add any additional targets detected. When each man has checked the stereo pairs, the men get together and discuss any conflicts. Under the immediate consensus method, each man performs initial interpretation on a copy of the same stereo pair. The men get together and discuss all conflicts. Under the control procedure, each man interpreted the imagery by himself and did not discuss or compare response data sheets with other interpreters.

Team consensus feedback methods gave significant performance increments over individuals practicing alone. Differences between the serial consensus and immediate consensus methods were negligible. The personnel benefiting most from the training were the relatively low performance interpreters. Most field interpretation units typically have a relatively large number of inexperienced personnel and a relatively small number of experienced personnel. A program in which recent interpretation school graduates and transferees can be given systematic practice exercises during slack periods offers promise for improving personnel proficiency.

In summary, a number of image interpreter training techniques are being investigated at BESRL. The experimental findings obtained to date indicate that three of the techniques show sufficient promise to warrant at least tentative inclusion in programs to maintain and enhance personnel proficiency in the field and perhaps in the classroom as well. The speed expansion technique of simply encouraging interpreters to systematically increase their speed, giving them time feedback and plenty of practice, seems effective in improving the rate of image interpretation. The error key approach and practice in error avoidance seem effective in reducing the number of inventive errors. Team consensus training seems effective in increasing detection and identification performance. All these techniques involve practice. As a matter of fact, the data support the contention that no matter what technique is used, increments in performance will result from practice--though some techniques produce greater increments than others. To date, no longitudinal data have been collected to study the effect of prolonged intermittent practice over periods lasting several months or years. However, with the emergence of new sensors, new targets, and new military situations, the skills of image interpreters will clearly need to be continually updated. The methods recommended above lend themselves readily to a long-term program of proficiency maintenance.

The case for computer-assisted instruction is perhaps not substantiated as yet, although the results of the initial experiment in this area were certainly encouraging. Advanced image interpretation facilities with their computers, data base, displays, and input/output devices provide ready-made beds for training. Hopefully, data from current and planned studies will indicate how these potentially powerful tools can best be used to enhance interpreter proficiency in the field. The potential application of CAI in the classroom will also be explored in future research. To this end, BESRL is planning in cooperation with the U. S. Army Intelligence School to place two terminal on-line stations at the School to conduct CAI research.

LITERATURE CITED

1. Beechler, R. L., S. W. Winterstein, and R. M. Kamper (IBM-OWEGO), and T. E. Jeffrey (BESRL). A study of rapid photointerpretation methods. BESRL Technical Research Report 1153. June 1969.

2. Sadacca, R., H. Martinek, and A. I. Schwartz. Image Interpretation Task--Status report, 30 June 1962. BESRL Technical Research Report 1129. October 1962.

3. Bolin, S. F., R. Sadacca, and H. Martinek. Team procedures in image interpretation. BESRL Technical Research Note 164. June 1965.

4. Doten, G. W. and J. T. Cockrell (System Development Corporation), and R. Sadacca (BESRL). The use of teams in image interpretation: Information exchange, confidence, and resolving disagreements. BESRL Technical Research Report 1151. October 1966.

5. Thomas, J. A. and R. Sadacca. Rapid screening of tactical imagery as a function of display time. BESRL Technical Research Note 189. June 1967.

6. Willmorth, N. E. (System Development Corporation). Influence of overlap in speed and accuracy in screening imagery. BESRL Technical Research Note 180. February 1967.

7. Lepkowski, J. R. (System Development Corporation). Effects of scale, resolution, and presentation rate on real-time imagery screening performance. BESRL Technical Research Note 213. August 1969.

8. Willmorth, N. E. (System Development Corporation) and A. H. Birnbaum (BESRL). Influence of screening and overlapping imagery in speed and accuracy of photo interpretation. BESRL Technical Research Note 182. April 1967.

9. Jeffrey, T. E. Effects of information requirements, timing procedures, and photo scale on interpreter performance. BESRL technical Research Note 211. July 1969.

10. Sadacca, R., A. Castelnovo, and J. Ranes. Human factors studies in image interpretation: The impact of intelligence information furnished interpreters. BESRL Technical Research Note 117. June 1961.

11. Thomas, J. A. and R. Sadacca. Ability of image interpreters to adapt output to varying requirements for completeness and accuracy. BESRL Technical Research Note 165. December 1965.

12. Thomas, J. A. Relative effectiveness of different methods of stating image interpretation requirements. BESRL Research Memorandum 66-2. June 1966.

13. McKendry, J. M. and P. C. Harrison, Jr. (HRB-Singer, Incorporated), and A. H. Birnbaum and R. Sadacca (BESRL). Estimating the value of surveillance information using error cost matrices. BESRL Technical Research Note 184. June 1967.

14. Levy, G. W., L. A. Evans, and J. M. Humes (North American Aviation, Incorporated), and R. Sadacca (BESRL). Probability indexes of image interpreter performance: Development and evaluation. BESRL Technical Research Note 183. June 1967.

15. Zeidner, J., R. Sadacca, and A. I. Schwartz. Human factors studies in tactical image interpretation: The value of stereoscopic viewing. BESRL Technical Research Note 114. May 1961.

16. Birnbaum, A. H. Effect of selected photo characteristics on detection and identification. Paper delivered at the International Congress of Photogrammetry Symposium, Delft, Holland, 29 August 1962.

17. Mathers, B. L. (System Development Corporation). Relative effectiveness of different viewing devices for photo interpretation. BESRL Technical Research Note 179. November 1966.

18. Klingberg, C. L. and C. L. Elworth (Boeing Company), and A. H. Birnbaum (BESRL). Effects of disparity in photo scale and orientation on change detection. BESRL Technical Research Note 206. January 1969.

19. Epstein, S. (System Development Corporation). Effects of image incongruence on location of common terrain in comparative cover. BESRL Technical Research Note 222. (in preparation).

20. Klingberg, C. L. and C. L. Elworth (Boeing Company), and S. Epstein (System Development Corporation). Change detection in aerial photo coverage as influenced by methods of comparison. BESRL Technical Research Note 205. January 1969.

21. Laymon, R. S. (System Development Corporation). Study of two image interpreter map displays: Chip versus hard copy. BESRL Technical Research Note 169. May 1966.

22. Jeffrey, T. E. Unaided reading of coded reconnaissance data. BESRL Technical Research Note 220. December 1969.

23. Birnbaum, A. H. Exploratory study in interpretation of vertical and high oblique photographs. BESRL Technical Research Note 174. June 1966.

24. Lepkowski, J. R. (System Development Corporation). Study of image interpreter use of aids and equipment. BESRL Research Study 69-4. April 1969.

25. Martinek, H. and R. Sadacca. Error keys as reference aids in image interpretation. BESRL Technical Research Note 153. June 1965.

26. Laymon, R. and M. A. Narva. Computer-aided entry methods and selected modes of signature presentation for reference information. BESRL Technical Research Note ___. (in preparation).

27. Clarke, F. R. and R. I. Welch (Stanford Research Institute). Development of a psychophysical photo quality study. (Unpublished study).

28. Sadacca, R. and A. I. Schwartz. Psychophysical aspects of image quality--Exploratory study. BESRL Technical Research Note 136. September 1963.

29. Brainard, R. W., L. J. Lopes, and G. N. Ornstein (North American Aviation, Inc.), and R. Sadacca (BESRL). Development and evaluation of a catalog technique for measuring image quality. BESRL Technical Research Report 1150. August 1966.

30. Evans, J. J., Mary A. Savas, and H. E. Abbott (Informatics), and R. S. Andrews (BESRL). Standard systems measurement methodology for image interpretation facilities. BESRL Technical Research Note ___. (in preparation).

31. Feallock, J. B. and J. M. Levine (North American Rockwell Corporation), and R. Sadacca and R. Andrews (BESRL). Method for quantifying subjective costs of large numbers of image interpretation errors. BESRL Technical Research Note 218. November 1969.

32. Root, R. T. and P. D. Gallagher (HRB-Singer, Inc.). Maintaining interpreter proficiency in a computerized facility--Experiment I: Programming and feedback method. BESRL Technical Research Note 209. March 1969.

33. Powers, J. R., 3d, R. W. Brainard, and R. E. Abram (Batelle Memorial Institute), and R. Sadacca (BESRL). Rapid detection training techniques for image interpreters. BESRL Technical Research Note ___. (in preparation).

34. Cockrell, J. T. (System Development Corporation). Maintaining image interpreter proficiency through team consensus feedback. BESRL Technical Research Note 195. April 1968.

APPENDIXES

PRECEDING PAGE BLANK

The BESRL Information Systems Laboratory (Figure A-1) provides a highly flexible controlled environment with the capability of human performance experimentation and evaluation ranging from that of the individual interpreters and associated equipment and methodological aids to that of a total semiautomated computerized information processing system. The total range and versatility of the experimentation is limited only by the state of the art in that equipment is modular in nature and can be configured and augmented to meet a multitude of requirements. The heart of the laboratory is the computer system, which includes the computer itself and peripheral equipment which drives or controls the on-line laboratory equipment. In addition, punched paper tape equipment and typewriter printers are provided for off-line or noncomputer based experimentation.

THE COMPUTER SYSTEM

The computer is a medium-scale general-purpose computer (CDC 3300)[1] which is time-shared for batch job statistical processing at the same time an experiment is in progress. The computer peripherals include a card reader, a card punch, a line printer, two magnetic tape units, three disc drives, a controller for driving the cathode ray tubes, and a controller for driving the other on-line laboratory equipments.

The computer system is depicted graphically in Figure A-2. The Central Processor (3304)[1] is the controlling unit comprising arithmetic control, input/output control, three index registers, a real-time clock, an operator's console, and an input/output typewriter. It performs both word and character manipulations. The Storage Modules (3302) are core memory storage units which each contain 16,384 words. Access time for one word in storage is 1.25 microseconds. Each of the four Data Channels (3306) is bi-directional and can transfer 12 bits in parallel. Each channel can operate asynchronously and simultaneously with each other and with the central processor. Either data channel may connect to the two disk controllers. The Disk Pack Controller (3290C) acts as a communications coordinator between the computer and the display CRTs. It provides display buffer memory, symbol generation and refreshing, and interface with the computer. It can control up to twelve CRTs and transfer data at a rate of up to 50,000 characters per second.

[1] Commercial designations are given only in the interest of precise description; their mention does not constitute indorsement by BESRL or by the Army.

PRECEDING PAGE BLANK

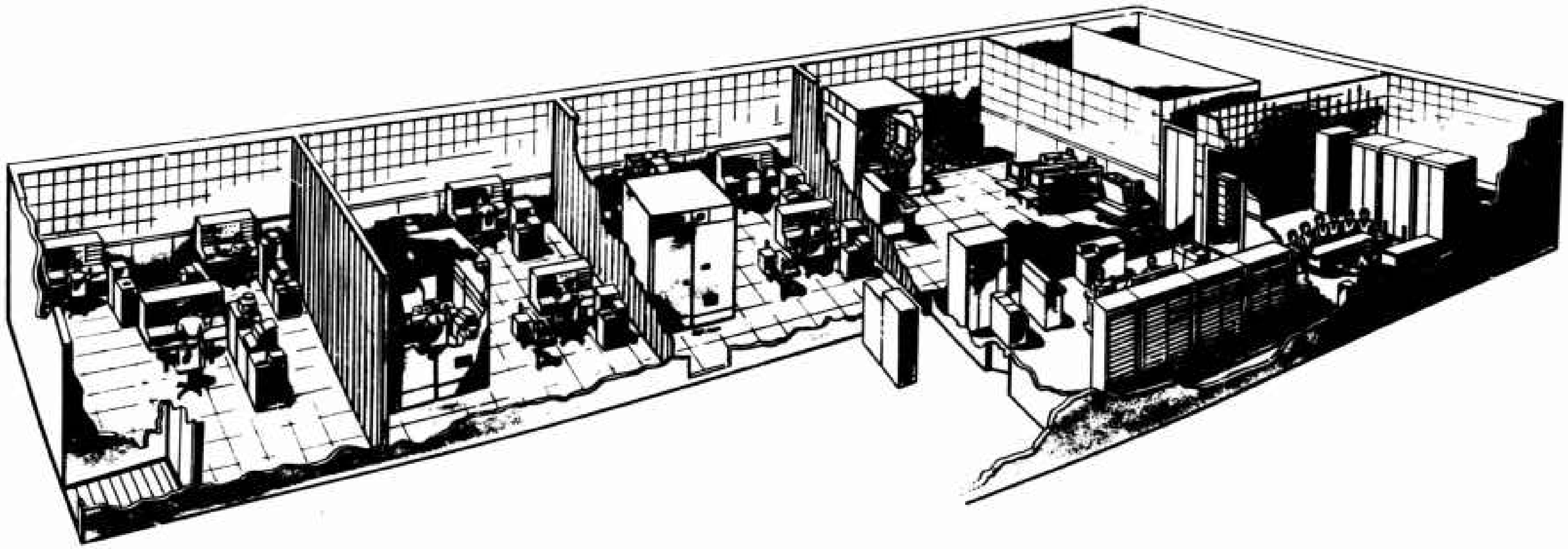


Figure A-1. Overview of the Information Systems Laboratory

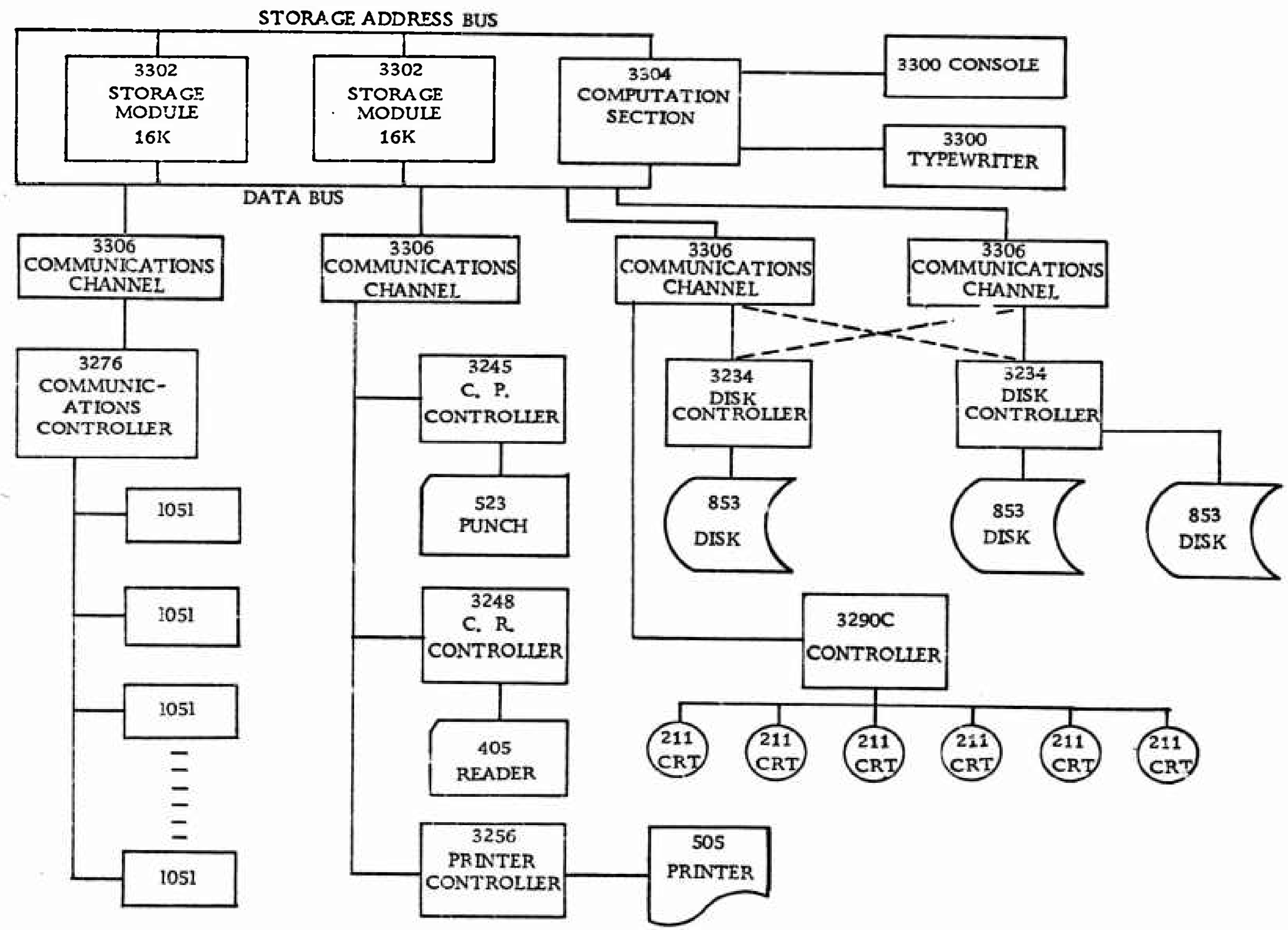


Figure A-2. CDC 3300 computer system

The unbuffered Card Reader Controller (3248) provides interface control for the Card Reader (405). The Card Reader operates at 1200 cards per minute and can read Hollerith or binary-coded punched cards. The Card Punch Controller (3245) furnishes intercommunication control between the Card Punch (523) and the central processor. Hollerith or binary-code cards can be punched at ranges up to 100 per minute. The Line Printer (505), prints 500 lines a minute, has a print span of 120 characters, and prints six lines per inch. A line buffer and controller are also furnished.

The line controllers provide a total of 22 subchannels for communication between the laboratory stations and the central processor. Each station can be modularly equipped with a variety of devices and served by one, two, or more subchannels.

LABORATORY EQUIPMENT

In addition to six automated light tables, the laboratory is equipped with a variety of display and input/output devices that can be connected on line with the computer as shown in Figure A-3. All laboratory equipment except the CRT devices operates through a 1051 control unit. The Control Unit controls all data flow into, through, and out of the 1050 system. The system provides for home-loop operation (transmitting to other units at the same laboratory station) or line-mode transmission to the computer and to other stations in the laboratory.

Automated Light Table. These units are basically table-like devices with a translucent top, a film transport mechanism, film take up spools at either end and a variable light source underneath the translucent panel. A close-up view of one of these tables is shown in Figure A-4. They have several unique features for aiding the interpreter in his task of extracting information from a film record and for facilitating the conduct of experiments. First and perhaps foremost is the fact that the light tables can communicate with the computer and thus can be considered an input/output device. Computer programs can be written which enable the computer to control the light table, and at the same time the computer can recognize light table functions that have been initiated by an operator. Computer control can cause selected indicator lights at the operator's console to go on or off, activate an audible alert at the light table, and regulate the rate and mode (continuous or stop-start) of film movement across the light table.

Specific responses can be communicated from the operator to the computer by depressing appropriate buttons on a 40-button response panel. Target location in terms of XY coordinate can be transmitted by positioning the reticle of the table tube magnifier over the target on the film and activating a foot switch. Frame marks passing under a photo-electric sensor generate signals which enable the computer to recognize film movement, direction and number of frames.

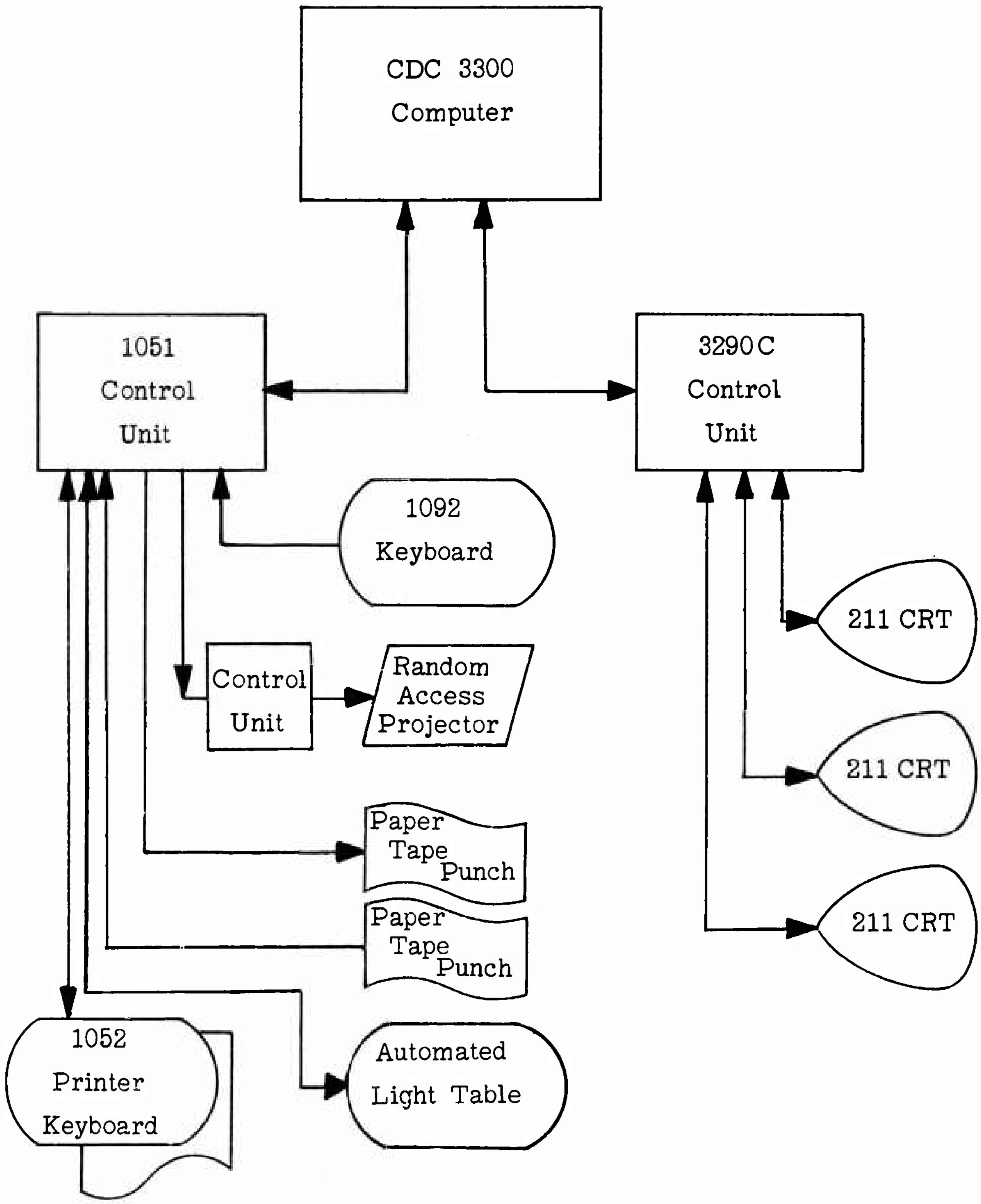


Figure A-3. ISL on-line components

Film speed is infinitely variable between .1 inch per second and 5 inches per second. As many as 4 different speeds can be preset and then automatically selected or reselected during the experiment. Precise timing of subject responses via the millisecond clock internal to the computer, and immediate statistical processing of responses can be achieved when the tables are operated on-line with the computer.

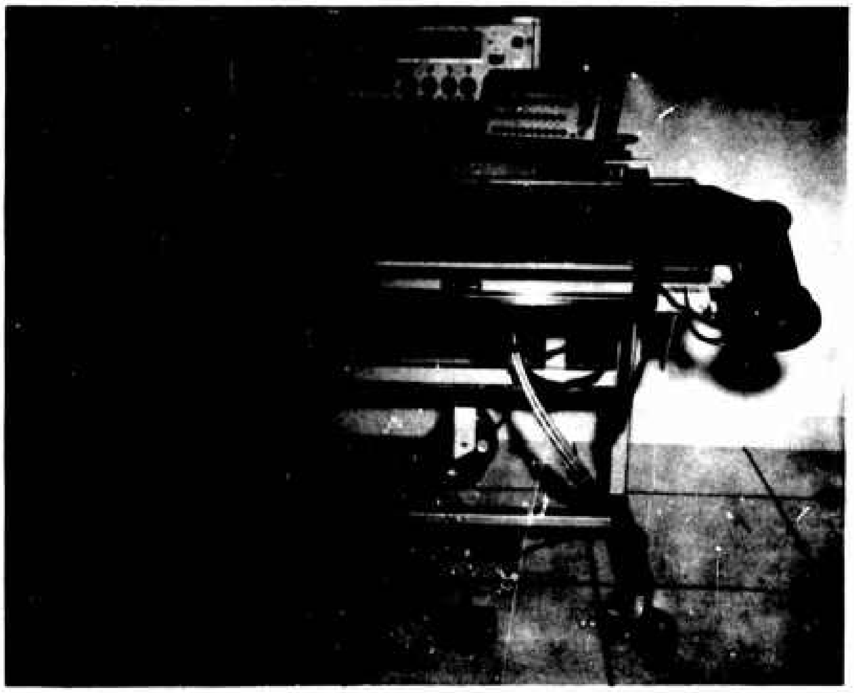


Figure A-4. The ISL automated light table with associated controls, register, and push button response panel

CRT Input/Output Display Device. As many as 12 of the electronic typewriter/display devices that allow two-way communication with the computer can be utilized in the laboratory. These devices consist of a typewriter keyboard and a bright CRT display screen. Each display page is 20 lines of 50 characters per line. The symbol repertoire consists of 63 characters. A controllable index marker indicates where the next character to be typed will appear. The screen may be filled with data by the operator and these data transmitted to the computer for processing, or the computer may fill the screen with data to be viewed by and acted upon by the operator. Transmitting to or from the computer requires only 40 milliseconds, so that to the subject it appears to be instantaneous.

Closed-Booth Image Interpretation Station. There are three closed-booth image interpretation stations. Typical of these is the one shown in Figure A-5. These stations provide essentially the same environmental support as the automated light tables but with a number of differences. The closed booth provides control over both sound and ambient light levels, so that the subject may be isolated from disturbing influences. The stations have rear view projectors with variable light intensity and magnification of the image under subject control. This equipment gives the subject "whole image" magnification up to 4 times for 5-inch film instead of the "spot" magnification obtained when a tube magnifier is used on the automated light table. Spot or area magnification up to 10 times is also possible with these devices. The subject selects the portion of the original frame that he wishes to view by translating in both the x and y directions. Rotation of the image up to 360° is also under subject control so that the subject may orient the image suitably. When a subject moves the image under the cursor or the cursor over a spot on the image, the type and amount of motion can be transmitted to the computer so that x-y coordinate location and measurements can be calculated. Indicator/response buttons are available for two-way communication with the computer. Auxilliary input/out devices such as the CRT can be located in the booth. The 1052 printer-keyboard is shown in the illustration.

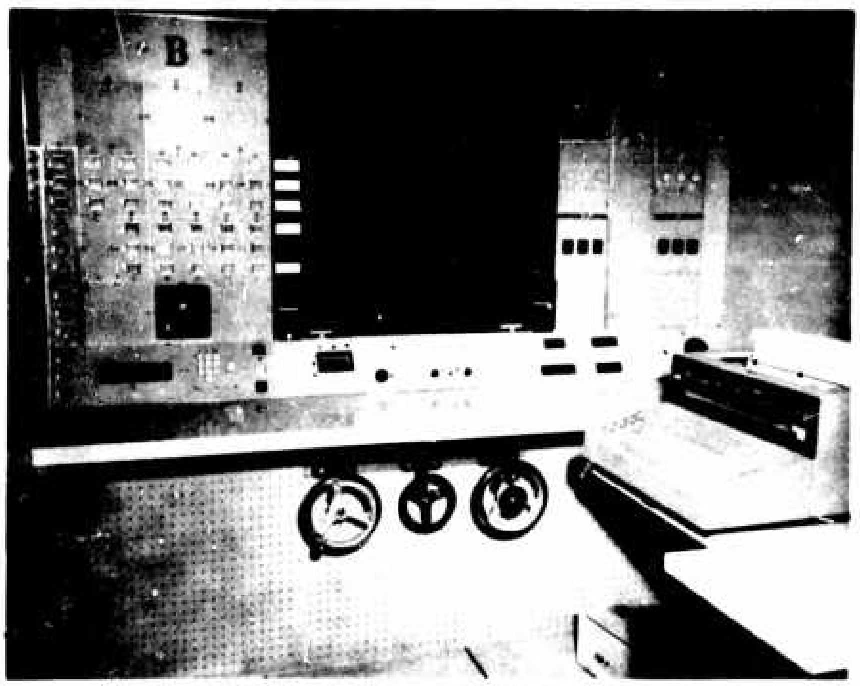


Figure A-5. A closed booth station showing the full frame magnification screen, controls, response push buttons and I/O typewriter-printer

Random Access Slide Projector. Four 70mm and two 35mm random access slide projectors can be directed by the computer or independently to display any slide in their carousels (sixty 70mm slides or one hundred 35mm slides). The time required to change from one slide to another depends on the distance between the two slides in the carousel and ranges from two to eight seconds. Movable iris lens and variable intensity of the projection lamp enable refined control of the projected image. The slides are normally projected onto rear-projection viewing screens for simulation of a variety of proposed information displays. Non-computer control can be effected remotely if desired.

Printer Keyboard (1052). There are five of these devices, each containing a printing mechanism and a typewriter keyboard. The printer can accept data from the computer, another station, the paper tape reader, or its own keyboard. The keyboard is also used to input data. The operator can type at any rate he chooses. Transmission is at the rate of 15 characters per second.

Paper Tape Punch (1055). The five units in BESRL's Information Systems Laboratory can record characters generated by the computer, the light table, the keyboard printer, or the programmed keyboard, providing a means of recording subject responses without the use of a computer. The information on the paper tape can be typed out or processed by the computer at a later time.

Paper Tape Reader (1054). The paper tape reader can read and transmit information which was previously punched on paper tape. The reader can operate the keyboard printer, the light table, and any of the other laboratory devices which can be operated by the computer with the exception of the CRTs. For example, a test of the light table can be placed on paper tape and used daily, or information to be presented to a subject can be placed on paper tape for use in a non-computer-based experiment.

Programmed Keyboard (1092). The six keyboards in the Information Systems Laboratory contain a matrix of buttons, with ten buttons in each column and sixteen columns. A keymat can be placed over the keyboard to show the meaning of each button. The keyboards can be used to transmit information to, or request information from, the computer or other devices. When the subject has composed a message by depressing selected buttons on the keyboard, the contents of the keyboard are transmitted to the computer by depressing a special button. Suppose this keyboard is to be used to identify a target. The first column of buttons might designate target type, the second column the status of the target (moving, firing position, etc.), the third column the location, etc. The subject enters his selections by depressing the appropriate buttons, checks his entries visually, then pushes a log button to transmit the information. In the case of requesting information, a display device (CRT or printer) would be needed to record the returning information.

CONSTRUCTING THE SSMB

Selection of the image interpretation functions to be represented was based on a previous study[1] wherein a concept for imagery interpretation in an advanced TIIF was evolved from functional task analysis, data on human and machine performance, and data on the frequency of task occurrence. The major functions, subfunctions, and tasks identified were revised to arrive at a more generalized list, excluding those unique to a specific configuration, since it is intended that the SSMB be equally applicable to a variety of configurations. Table B-1 is a listing of the functions and subfunctions represented.

The echelon of operation to be simulated was determined to be corps level, primarily on the basis that this is the lowest level under current Army doctrine having organic aircraft. The anticipated capability of a TIIF is such that it was felt neither the full diversity of activities and requirements or a sufficiently taxing workload could be realistically imposed in lower echelons not having organically assigned aircraft. Further recourse to standard Army doctrine regarding imagery interpretation requirements and operations at corps level provided the basis for determining the appropriate types of target, activities to be interpreted, reporting requirements, and relationship of the image interpretation facility to G2 Air and the command organization.

Guided by the above determinations, the desired test characteristics were specified for the major test components--inputs, requirements, and outputs as shown in Table B-2. Overlaying all these characteristics was the additional requirement for a realistic and coherent scenario that would effectively bond together all elements of the test and convey to the image interpreter both explicitly and implicitly the performance demands of the situation depicted.

Imagery was selected, SOP's and reporting requirements established and supporting documentation selected and/or prepared--scenario, report forms, Essential Elements of Information, Standing Requirements List, Mission Requests, Mission Plans, Pilots Debriefs, Maps, Pilots Flight Traces, Special Requests for Information, Photo Intelligence Data Cards, and school solution. Concurrently, data collection and processing plans were formulated which would allow evaluation of total system effectiveness and the relative contribution of various system components to total performance in terms of accuracy, completeness, and time. In addition, provision was made for obtaining directly, or deriving, appropriate

---

[1] Hansen, O. K., K. R. Colson, and L. Vettese (Nortronics) and H. C. Strasel (BESRL). Method for developing a laboratory model of an image interpretation system (Unclassified Title).

measures of performance for some of the internal operations and procedures and the behavior of personnel which could conceivably affect system performance. All materials were organized and integrated, and input schedules established. Instructional booklets were prepared to assist interpreters in understanding the nature and purpose of the exercise and the requirements to be imposed. Test management handbooks were developed to provide specific guidance to experimenters regarding the administration of the test, the sequence of events, and data collection and processing procedures.

Table B-1

FUNCTIONS AND SUBFUNCTIONS TO BE REPRESENTED IN THE STANDARD SYSTEMS TEST

FUNCTION	SUBFUNCTION
Pre-mission Notification and Preparation	Receive Mission Plan (Does not include SRI's) (6 tasks)
	Pre-mission Preparation (9 tasks)
Specific Request for Information Processing (SRI)	Receive and Evaluate Specific Request for Information (SRI) (4 tasks)
	Answer SRI from Available Imagery (7 tasks)
Preparation for Imagery Analysis	Receive Mission Imagery (hand delivered) (6 tasks)
	Prepare for Interpretation (8 tasks)
Analyze and Interpret Imagery	Analyze some Imagery for Hot Report when specifically required (17 tasks)
	Analyze Photo and IR coverage for Immediate or Detailed Report (27 tasks)
	Analyze SLAR Coverage (7 tasks)
Reporting	Prepare Hot or Immediate Report (3 tasks)
	Prepare Detailed or Special Reports (3 tasks)
Post Mission Operations	Return Internal Reference Material to Storage (4 tasks)

Table B-2

DESIRED TEST CHARACTERISTICS

TESTS COMPONENT	DESIRED CHARACTERISTICS
Inputs	Comparative cover of contemporary military targets and situations
	Multi-sensor imagery and formats
	Compatible with corps level of II operations
	Ground truth or school solution obtainable
	Map coverage and supporting documentation available
	Sufficient quantity of imagery to provide for several days of training and testing
	Security classification mostly unclassified and in no event higher than confidential
Requirements	Clear statement of image interpretation processes to be performed
	Elicit performance of representative functions
	Compatible with corps level operations
	Must be generalizable across a variety of systems
	Must evoke objectively scorable responses
Outputs	Representative of Army operational reports
	Scorable in terms of timeliness, accuracy, and completeness
	Comparable to school solution in form and content
	Sufficient quantity to produce reliable results

MODEL CONCEPTUALIZATION

Steps in the model development include 1) analysis of TIIF-type functions and tasks, 2) determination of manned-position types for task performance, 3) investigation of manual vs semiautomated options for certain subfunctions, and 4) investigation of the suitability of the model to meet the requirements for a system at the corps level of tactical usage. Particular attention was given the sharing of systems work between the man and the machine. The man was to be assisted and guided, but he was not to be driven by the automated subsystems in the accomplishment of his tasks. The result of these analyses was a conceptual model of the image interpretation system in terms of the processes, personnel, and equipment within the structural framework of an expansible van.

The model TIIF specifies six image interpretation stations which can accommodate up to eight interpreters. The floor plan is presented in Figure 3 in the text. Stations A and B are configured for rear projection viewing of imagery and selected references. Station A is designed to be capable of near real-time viewing and interpretation by processing and projecting imagery transmitted from the reconnaissance aircraft via a telemetry data link. Stations C, D, and E provide light-table viewing of image transparencies from all standard reconnaissance sensors. The five stations (A through E) are connected to the computer through individual controls. Station F is a manually-operated backlighted drafting table that is used for plotting and for comparison viewing of imagery in the larger formats, such as two 9-inch film rolls. Station G is a communications teletypewriter.

For field use, the model TIIF was designed to fit into an expansible van that was 7½ feet wide by 17 feet long in transport, and 13½ by 17 feet overall when opened. To conform to these dimensions, the fixed equipment was arranged along the major axis of the van. The movable sides were kept free of equipment except for folding shelves and seats, so that the wall space can be used to display maps and plots. Because of the limited space, a small computer will be programmed to perform limited support functions such as translating digitally recorded flight data, retrieving and displaying references, managing system files, composing reports, performing routine computations and communicating with other systems. The image interpretation and system management operations are to be performed by the intelligence personnel generally assigned to such a facility.

<u>Simulation of the Model</u>. Prior to constructing the simulation in the laboratory, the following guidelines were established:

1. The simulation was to be composed of available laboratory equipment.

2. The physical dimensions and configuration of the individual station equipment were to duplicate as closely as possible those of the model.

3. The simulation was to be given the capability of performing all the functions required by the SSMB.

4. Functions not required for the system test were to be only hypothecated in the simulation.

5. The computer was to be programmed to perform only the support operations envisioned for the actual TIIF in the field.

6. The excess computer capability was to be used to simulate functions not satisfactorily provided by the laboratory equipment and to collect test data.

7. The operating procedures for the simulation were to reflect current Army doctrine regarding image interpretation operations in the field.

These guidelines were particularly useful in controlling the tendency to endow the simulation with capabilities that the fieldable TIIF would not have.

The floor plan, Figure 4 in the text, illustrates how closely the laboratory simulation resembles the conceptualized model. However, several compromises had to be made, primarily to accommodate the size and bulk of the laboratory equipment at each station. None of these compromises appear to be of the type which would seriously alter the functional representation. Fortunately, the inventory of laboratory equipment included materials which can very satisfactorily duplicate the primary functional systems needed at each station. Furthermore, the CDC 3300 computer[a] capabilities not only met, but exceeded, those needed to duplicate the support processes of the much smaller computer envisioned for the model. As a result, a substantial portion of software development was straightforward implementing of the computer and the peripheral equipment to perform designated functions, and a minor portion was devoted to simulating missing equipment. Whenever modifications in computer operations, programming, and operator procedures were made, the prime objective was to endow the simulation with only those man-machine interfaces and procedures that were prescribed for the model.

[a] Commercial designations are given only in the interest of precise description; their mention does not constitute indorsement by BESRL or by the Army.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U. S. Army Behavioral Science Research Laboratory, Arlington, Virginia	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP
3. REPORT TITLE SUMMARY OF BESRL SURVEILLANCE RESEARCH	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)	
5. AUTHOR(S) (First name, middle initial, last name) A. H. Birnbaum, Robert Sadacca, R. S. Andrews, and M. A. Narva	

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1969	61	34

8a. CONTRACT OR GRANT NO. b. PROJECT NO. DA R&D Proj. No. 2Q662704A721, 2Q662704A732 c. d. Surveillance Systems	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Research Report 1160 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
10. DISTRIBUTION STATEMENT This document has been approved for public release and sale; its distribution is unlimited.	
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Office, Chief of Research and Development, Wash., D. C.

13. ABSTRACT

The SURVEILLANCE SYSTEMS research program of the U. S. Army Behavioral Science Research Laboratory has as its objective the production of scientific data bearing on the extraction of information from surveillance displays and the efficient storage, retrieval, and transmission of this information within an advanced computerized image interpretation facility. The present technical research report summarizes in integrated fashion the major problem areas, the rationale of BESRL's approach to their solution, and the general course of research studies completed or in progress in the surveillance areas of manned systems experimentation. The research effort is conducted within the following Work Units: 1) Interpreter Techniques--The determination of interpreter techniques in a surveillance facility; 2) Image Interpretation Displays--Influence of displays on image interpreter performance; 3) Intelligence Systems--Intelligence information processing systems; 4) Image Systems--Information processing in advanced image interpretation systems. Studies of the Surveillance Systems research programs conducted by the Support Systems Research Division of BESRL have resulted in findings which are applicable in optimizing human component performance in existing systems and in providing systems developers with information useful in design specifications for future systems.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Interpreter techniques						
Image interpretation displays						
*Intelligence systems						
*Image systems						
*Surveillance facility						
*Summary - surveillance research program						
Information assimilation						
Information processing						
Information storage - retrieval						
Laboratory facilities						
Aerial surveillance						
Feedback techniques						
Computer-compatible interpreter procedures						
TIIF						
Image systems models--task--functions						
*Systems evaluation--Measurement--Methodology						
Simulated computer procedures						
Field command and control facilities						
Interpreter team performance						
Interpreter performance measures						
*Data bank utilization						
Advanced computerized systems						
*Man/computer decision processes						
*Computer aided instruction (CAI)						
Photointerpretation systems--techniques						

A17890